Appendix-51
Resolution No. 24-13

Master of Operational Research

Two Year Programme

(PG Curriculum Framework 2024 based on NEP 2020)

Academic Session 2025-26

Department of Operational Research
Faculty of Mathematical Sciences
University of Delhi
Delhi – 110007

Department of Operational Research, University of Delhi

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Department of Operational Research, University of Delhi

PG Curriculum Framework 2024 based on NEP 2020

Course Structure: Sem-I to Sem-IV, Structure-1 & Structure-2 of Two-Year PG Program in Operational Research, PGCF

1st year of PG curriculum structure for 2-year PG Program

Semester	**DSC (12 Credits)**	**DSE 1, DSE 2 (8 credits) OR DSE 1 & GE 1 (8 credits)**	**Skill-based Course (2-credit course)**	**Dissertation/Academic Project/Entrepreneurship**	**Total Credits**	**One GE to be offered by the Department**
	Credit Distribution: (4 * 3) = 12	**Credit Distribution: (4 * 2) = 8**	**Credit Distribution: (2*1) = 2**		**(12+8+2) = 22**	
Sem I	DSC-1: Inventory Management DSC-2: Linear Programming & Extensions DSC-3: Statistics	Any **two** of the following: DSE-1(a): Mathematics for OR DSE-1(b): Decision Theory DSE-1(c): Design Thinking and Innovation DSE-1(d): Game Theory with Behavioral Aspects DSE-1(e): Simulation Modeling DSE-1(f): Software Engineering	Database Management System	Nil		Any **one** of the following: GE-1(a): Inventory Management GE-1(b): Linear Programming & Extensions GE-1(c): Game Theory with Behavioral Aspects GE-1(d): Simulation Modeling

Sem II	DSC-4: Optimization Techniques DSC-5: Queueing Theory DSC-6: Python Programming for Decision-Making	Any **two** of the following: DSE-2(a): Applied Multivariate Analysis DSE-2(b): Financial Management DSE-2(c): Fundamentals of Managerial Economics DSE-2(d): Marketing Research DSE-2(e): Quality Management DSE-2(f): Soft Computing	Spreadsheet and Data Visualization	Nil	22	Any **one** of the following: GE-2(a): Queueing Theory GE-2(b): Marketing Research GE-2(c): Quality Management GE-2(d): Soft Computing

Structure 1 (Level 6.5): PG Curriculum Structure with only course work

Semester	**DSC (8 credits)**	**DSE (12 credits)**	**Skill-based course/workshop/Specialized Laboratory/Internship/Apprenticeship/Hands- on Learning (2credits)**	**Dissertation/Academic Project/Entrepreneurship**	**Total Credits**
Sem III	DSC-7: Econometric Modeling & Forecasting DSC-8: Marketing Management	*	**	NIL	22
Sem IV	DSC-9: Reliability & Maintenance Theory DSC-10: Scheduling Techniques	*	**	NIL	22

Department of Operational Research, University of Delhi

Structure 2 (Level 6.5): PG Curriculum Structure with only course work + Research

Semester	DSC (8 credits)	DSE (8 credits)	Skill-based course/workshop/Specialized Laboratory/Internship/Apprenticeship/Hands-on Learning (2credits)	Dissertation/Academic Project/Entrepreneurship	Total Credits
Sem III	DSC-7: Econometric Modeling & Forecasting DSC-8: Marketing Management	*	NIL	(6 credits)	22
Sem IV	DSC-9: Reliability & Maintenance Theory DSC-10: Scheduling Techniques	*	NIL	(6 credits)	22

*** POOL OF TENTATIVE DSE COURSES IN SEMESTER-III & SEMESTER- IV, STRUCTURE 1 AND STRUCTURE 2**

S. No.	Title of the paper
i.	Health Care Management
ii.	Revenue Management
iii.	Supply Chain Management
iv.	Advanced Inventory Management
v.	Queueing Networks
vi.	Multicriteria Decision-Making Techniques
vii	Data Warehousing and Data Mining
viii.	Dynamic Optimization
ix.	Portfolio Optimization
x.	Stochastic Modeling
xi.	Advanced Marketing Management
xii.	Social Media Analytics
xiii.	Marketing Analytics
xiv.	Text Analytics for Management
xv.	Pattern Recognition
xvi.	Deep Learning
xvii.	Advanced Software Reliability Models
xviii.	Fuzzy Sets & Logic
xix.	Numerical Optimization

xx.	Logistics and Network Optimization
xxi.	Financial Modeling
xxii.	Warranty Modeling & Analysis
xxiii.	Bayesian Forecasting
xxiv.	Reliability Testing & Prediction
xxv.	Prognostics & Health Management of Systems
xxvi.	Bayesian Reliability
xxvii.	Design & Analysis of Experiments
xxvii.	OR for Public Policy
Any other paper would also be added to this pool if need be.	

** Skill-based course/workshop/Specialized Laboratory/Internship/Apprenticeship/Hands-on Learning (2credits): To be decided later.
*** GEs to be offered by the Department in Semester-III & Semester-IV(4 credits): To be decided later.

Based on Postgraduate Curriculum Framework 2024 based on NEP 2020

MASTER OF OPERATIONAL RESEARCH

DEPARTMENT OF OPERATIONAL RESEARCH

UNIVERSITY OF DELHI

POSTGRADUATE PROGRAM OF STUDY

SYLLABI OF SEMESTERS I & II

Discipline Specific Core - Semester I

DSC - 1: Inventory Management

DSC - 2: Linear Programming & Extensions

DSC - 3: Statistics

Department of Operational Research, University of Delhi

DISCIPLINE SPECIFIC CORE
DSC-1: INVENTORY MANAGEMENT

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Prerequisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Inventory Management (DSC-1)	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- To impart knowledge of the role of inventory in organizations and core concepts of inventory management with an understanding of fundamental inventory control procedures and their usage.
- To provide students with a thorough understanding of basic inventory models and a rigorous mathematical framework to develop mathematical models to analyze and optimize inventory systems.
- To provide the students with a comprehensive study of various application areas of inventory models through case studies and relevant examples.

Learning Outcomes:

Students completing this course will be able to:

- Identify the goals and objectives of inventory management and describe the importance of stocks in an organization and the reasons for holding stock.
- Explain the various costs related to the inventory system.
- Understand the various selective inventory control techniques and their applications.
- Capability to develop deterministic inventory models: economic order quantity and its extensions, All units and incremental quantity discounts models, Joint and Individual order policies, and Production scheduling models.
- Understand and develop stochastic inventory models and setting safety stocks. Apply and extend inventory models to analyse real-world systems.

Syllabus of DSC-1:

Unit I: Introduction to Inventory Systems **(9 hours)**

Analytical structure of Production and Inventory problems. Objectives of Inventory Management. Factors influencing inventories. Inventory-related costs. Properties of Inventory systems. Selective Inventory control techniques and their applications. Concept of Lead Time. Introduction to Just in Time (JIT) and Vendor Managed Inventory (VMI).

Unit II: Deterministic Inventory Models **(15 hours)**

Deterministic inventory models, economic order quantity and its extensions: without and with lead time. Finite replenishment rate Inventory models without and with planned shortages. Inventory models with partial backlogging and lost sales. Discrete Demand Model. Multi-item Inventory models with constraints. Quantity discounts: All units and incremental. Joint and Individual Ordering Policies.

Unit III: Production Planning Models **(9 hours)**

Aggregate Production Planning Models: Fixed workforce model. Variable workforce model. Dynamic lot size models: Wagner-Whitin Algorithm, Silver-Meal heuristic.

Unit IV: Stochastic Inventory Models **(12 hours)**

Stochastic Inventory models, Newsvendor model and its extensions: Instantaneous and uniform demand with discrete and continuous cases; without and with lead time. Transformations for the equivalence of instantaneous and uniform demand models. Power demand pattern inventory model. Periodic review models. Safety stocks, Service levels and reorder level.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Axsäter, S. (2015). *Inventory Control.* (Third Edition). Springer.
2. Hadley, G., & Whitin, T. M. (1963). *Analysis of Inventory Systems*. Prentice-Hall.
3. Johnson, L.A., & Montgomery, D.C. (1974) *Operations Research in Production Planning, Scheduling and Inventory Control*. Wiley, New York.
4. Muckstadt, J. A., & Sapra, A. (2010). *Principles of Inventory Management: When You Are Down to Four, Order More*. Springer Science & Business Media.
5. Naddor, E. (1966). *Inventory Systems*. Wiley.
6. Silver, E. A., Pyke, D. F., & Peterson, R. (1998). *Inventory Management and Production Planning and Scheduling*. (Third Edition). Wiley.
7. Waters, D. (2008). *Inventory Control and Management.* (Second Edition). John Wiley & Sons.
8. Zipkin, H. P. (2000). *Foundations of Inventory Management*. McGraw-Hill.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE
DSC-2: LINEAR PROGRAMMING AND EXTENSIONS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Linear Programming and Extensions (DSC-2)	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- To impart knowledge of formulating practical problems using the linear programming method and its extensions.
- To understand the theoretical basics of different computational algorithms for solving linear programming and related problems.

Learning Outcomes:

Students completing this course will be able to:

- Describe the basic concepts of convex analysis and explain the theoretical foundations of various issues related to linear programming modelling.
- Formulate real-world problems as a linear programming model and describe the theoretical workings of the graphical and simplex methods.
- To solve linear programming problems using advanced simplex methods.
- Explain the relationship between a linear program and its dual, including weak and strong duality, complementary slackness, and sensitivity analysis.
- Formulate specialized linear programming problems, namely transportation, transshipment, and assignment problems, and describe the theoretical workings of the solution methods.

Syllabus of DSC-2:

Unit I: Foundations of Linear Programming **(10 hours)**

Theoretical Foundations: Linear independence and dependence of vectors, Basis, Convex sets, Extreme points, Hyperplanes and half spaces, Polyhedral sets and cones. Results based on the above concepts. Introduction to Linear Programming. Problem formulations from different industries.

Unit II: **Simplex Method and Duality** **(13 hours)**

Theory of simplex method. Simplex method, including The Big M and Two-Phase methods. Degeneracy in Simplex Method. Definition and importance of duality. Formulating dual problems. Economic interpretation of duality. Weak and strong duality results. Complementary slackness.

Unit III: **Advanced Simplex Methods, Sensitivity Analysis and Transportation Problem** **(12 hours)**

Advanced Simplex Methods: Revised simplex method, Dual-simplex method. Sensitivity analysis for Structural and Parameter changes. Transportation problem: Mathematical model, Balanced and unbalanced problems. Degeneracy. Optimality conditions. Methods to find initial and optimal solutions.

Unit IV: **Transshipment and Assignment Problems** **(10 hours)**

Transshipment Problem: Extension of transportation problem to transshipment model, Formulation and solution. Assignment problem: Mathematical model, Balanced and unbalanced problems. Optimality conditions. Hungarian method for optimal assignment.

Tutorial component (if any) – Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Bazaraa, M. S., Jarvis, J. J., & Sherali, H. D. (2010). Linear Programming and Network Flows. John Wiley & Sons, Inc.
2. Chandra, S., Jayadeva, & Mehra, A. (2009). Numerical Optimization with Applications. New Delhi: Narosa Publishing House.
3. Hillier, F.S., Lieberman, G. J., & Nag, B. (2021). Introduction to Operations Research, (11th ed.). New Delhi: Tata McGraw Hill (Indian print).
4. Taha, H. A. (2019). Operations Research: An Introduction (10th ed.). New Delhi: Pearson (Indian print).

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE
DSC-3: STATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistics (DSC-3)	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The aim of this course is to:
- Acquaint the students with the fundamental concepts of probability and statistics.
- Provide an understanding of the processes by which real-life statistical problems are analysed.
- Develop an understanding of the role of statistics in Operational Research.

Learning Outcomes:

Students completing this course will be able to:
- Quantify uncertainty using probability, learn how to find probability using the concepts of random variables and distribution functions, obtain characteristics of the underlying distributions, and study functional relationships between two random variables.
- Know various discrete and continuous probability distributions along with their characteristics and identify the situations where they provide realistic models.
- Learn about sampling and sampling distributions along with their characteristics which will help them analyze the population or phenomenon from which the sample is drawn.
- Learn inferential methods wherein the distributional form of population or phenomenon from which the sample is drawn is either known (parametric) or unknown (nonparametric).
- Learn how prior information about a parameter can be used to obtain updated information through Bayesian statistics.

Syllabus of DSC-3:

Unit I: Probability **(9 hours)**

Probability axioms, Conditional probability, Independent events; Random variable, Joint, Marginal and Conditional distributions, Independent random variables, Transformation of one and two- dimensional random variables; Moments: Mean, Variance, Expected value of a function of random variable, Conditional expectation and applications, Probabilistic inequalities, moment inequalities, characteristic functions; Karl Pearson's correlation coefficient and its properties.

Unit II: Distributions and Large Sample Theory **(8 hours)**

Discrete distributions: Degenerate distribution, Bernoulli and Binomial distributions, Hypergeometric distribution, Poisson distribution, Geometric and Negative Binomial distributions; Continuous distributions: Uniform distribution, Normal distribution, Exponential and Gamma distribution, Beta distribution; Weak law of large numbers; Central limit theorems (CLTs).

Unit III: Sampling and Sampling Distributions (12 hours)
Population and sample, Statistic, Sample mean, Sample variance, and Sample moments; Order Statistic: Distribution of smallest order statistic and largest order statistic; Chi-Square distribution; F-distribution; Students t- distribution.

Unit IV: Inferential Problems (16 hours)
Parametric inference: Problem of point estimation, Method of maximum likelihood estimation, Simple and composite hypotheses, Likelihood ratio tests, Construction of confidence intervals, p value; Parametric tests: normal tests for proportion and mean based on single sample; Chi-Square test for variability; t-test for single mean; t-test for difference of means; paired t-test; F test for equality of variances; Nonparametric tests: run test for randomness, Chi-square test for goodness of fit, one-sample sign test, Wilcoxon signed-rank test; Basics of Bayesian statistics: Bayes theorem, Bayes theorem for future events, Bayes theorem given the data, Conjugate prior distribution: normal conjugate, prior and posterior odds, Bayes factor for simple v/s simple hypothesis, Predictive inference: standard predictive distribution, Laplace's rule of succession.

Tutorial component (if any) - Yes (15 hours)

Practical component (if any) - Nil

Essential Readings:

1. Bansal, A. K. (2007). Bayesian Parametric Inference, Narosa Publishing House, New Delhi.
2. Berger, J. 1985. *Statistical Decision Theory and Bayesian Analysis*. New York: Springer-Verlag.
3. Feller, W. (2008). *An introduction to probability theory and its applications (volume 1)* (3rd ed.). Wiley.
4. Fruend, J. E. (2013). *Mathematical statistics with applications* (8th ed.). Pearson Education India.
5. Ross, S. M. (2014). *Introduction to probability models* (11th ed.). Academic press.
6. Levin, R. I., Masood, H. S., Rubin, S. D., & Rastogi, S. (2017). *Statistics for management* (8th ed.). Pearson Education.
7. Mood, A. M., Grabill, F. A., & Boes, D. C. (1974). *Introduction to the theory of statistics* (3rd ed.). McGraw Hill.

Suggested Readings:

1. Blake, I. F. (1987). *An Introduction to Applied Probability*. United States: R.E. Krieger Publishing Company.
2. Black, K. (2013). *Applied business statistics: making better, business decisions* (7th ed.). John Wiley & Sons.
3. Dudewicz, E. J., & Misra S. N. (1988). *Modern mathematical statistics*. Wiley.
4. Goon, A. M., Gupta, A. K., & Dasgupta, B. (1989). *An outline of statistical theory (volume 1)* (2nd ed.). World Press Pvt. Ltd.
5. James, G., Witten D., Hastie, T., Tibshirani, R., Taylor, J. (2021), *An Introduction to Statistical Learning, with Applications in R* (latest edition)., Springer.
6. Rohatgi, V. K., & Ehsanes Saleh, A. K. Md. (2000). *An introduction to probability and statistics* (2nd ed.). Wiley.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Discipline Specific Elective – Semester I

DSE - 1(a): Mathematics for Operational Research

DSE - 1(b): Decision Theory

DSE - 1(c): Design Thinking and Innovation

DSE - 1(d): Game Theory with Behavioral Aspects

DSE - 1(e): Simulation Modeling

DSE - 1(f): Software Engineering

DISCIPLINE SPECIFIC ELECTIVE
DSE-1(a): MATHEMATICS FOR OPERATIONAL RESEARCH

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Mathematics for Operational Research (DSE-1(a))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- To equip students with analytical skills and computational techniques focusing on linear algebra, ordinary differential equations, numerical methods, and graph theory.
- To equip students for analyzing and solving real-world Operational Research problems using these mathematical methods.

Learning Outcomes:

By the end of this course, students will be able to:

- Apply mathematical techniques to solve linear systems and analyze key properties of matrices and vectors.
- Solve and analyze different types of differential equations and apply methods to model real- world phenomena.
- Utilize numerical methods for approximating solutions to complex problems in mathematics and applied fields.
- Understand and apply concepts from graph theory to solve optimization and network-related problems.

Syllabus of DSE-1(a):

Unit I: Linear Algebra **(10 hours)**

Vector Space, Basis and dimension of a vector space, Linear independence and linear dependence of vectors, Solution of a system of linear equations: Gauss Elimination Method (with and without Pivoting), Eigenvalues, Eigenvectors, Eigenspace, Cayley-Hamilton theorem. Diagonalization of matrices. Computation Tools: MATLAB or Python.

Unit II: Ordinary Differential Equations **(12 hours)**

First-order exact differential equations and integrating factors, Linear equations and Bernoulli equations. Higher-order linear differential equations, Homogenous linear equations with constant coefficients, Non-homogenous linear equations, method of undetermined coefficients, and method of variation of parameters. Applications to the Growth and Decay modelling. Computation Tools: MATLAB or Python.

Unit III: Numerical Methods **(12 hours)**

Errors, Roots of Transcendental and Polynomial Equations: Bisection, Newton-Raphson and Secant methods. Order and Rate of convergence. Interpolation: Lagrange and Newton interpolation. Numerical integration: Trapezoidal and Simpson's rules. Computation Tools: MATLAB or Python.

Unit IV: Fundamentals of Graph Theory **(11 hours)**

Graphs: Definition and basic properties, Subgraphs, Complete graphs, and Bipartite graphs. Euler and Hamiltonian paths. Adjacency matrices. Introduction to trees and minimum spanning trees. Applications of graph theory in Network scheduling and optimization. Computation Tools: MATLAB or Python.

Tutorial component (if any) – Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Kolman, Bernard, & Hill, David R. (2001). Introductory Linear Algebra with Applications (7th ed.). Pearson Education, Delhi. First Indian Reprint 2003.
2. Ross, Shepley. L. (2012). Differential Equations (3rd ed.). John Wiley & Sons.
3. Jain, M. K., Iyengar, S. R. K., & Jain, R. K. (2012). Numerical Methods for Scientific and Engineering Computation (6th ed.). New Age International Publisher, India.
4. Gerald, C. F., & Wheatley, P. O. (2008). Applied Numerical Analysis (7th ed.). Pearson Education. India.
5. Rosen, Kenneth H. (2012). Discrete Mathematics and its Applications, with Combinatorics and Graph Theory. (7th ed.). McGraw-Hill Education. Indian Reprint.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE
DSE-1(b): DECISION THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Decision Theory (DSE - 1(b))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

- To teach how optimal choice can be made amongst alternative courses of actions with uncertain consequences using non-probabilistic, probabilistic and utility theory approaches.
- To construct and analyze decision support systems using decision trees and Bayesian decision networks.

Learning Outcomes:

Students completing this course will be able to:

- Analyze problems related to decision making under various environments: under strict uncertainty, under risk: probabilistic approach - without and with data, using utility theory approach.
- Analyze problems related to decision-making involving group of individuals.
- Make decisions with first, second and third degree stochastic dominance decision rules that enable partial ordering amongst competing alternatives; which are helpful in investment decision-making, agriculture, medicine, etc.
- Analyze problems related to sequential decision making under uncertainty.
- Use graphical approach- decision trees and Bayesian decision network for making decisions and apply simulation to decision problems.

Syllabus of DSE-1(b):

Unit I: Introduction **(5 hours)**

Prescriptive decision analysis; history of decision analysis; Basic elements of decision analysis; Modeling of Decision Problems; Decision Making under Strict Uncertainty: Maximin- Minimax criterion, Maximax-Minimin criterion, Hurwicz criterion, Savage's minimax regret criterion, Laplace equi-likelihood criterion, Some reasonable Properties of a Decision Rule, Analysis of criteria; Strict Uncertainty Impossibility Theorem.

Unit II: Decision Analysis under Risk **(15 hours)**

Probabilistic Approach- Bayesian Decision Theory: Prior, Posterior, and Preposterior analyses; Decision Analysis without Sampling; Decision Analysis with Sampling; Utility Theory Approach - St. Petersburg Paradox, Expected Utility Principle, Construction of Utility Functions, Risk Attitudes, Properties of Risk Aversion for Monetary Consequences: Utility theory and insurance; Multidimensional utility; Decisions involving groups of individuals; Stochastic Dominance Decision Rules.

Unit III: Sequential Decision Making under Uncertainty (10 hours)
Markov Decision Processes (MDPs) - An introduction, Bandit Problems, Decision-Theoretic Bandit process, Finite Horizon MDPs.

Unit IV: Decision Diagrams and Simulation (15 hours)
Decision Trees; Applying simulation to Decision Problems; Bayesian Decision Networks.

Tutorial component (if any) - Yes (15 hours)

Practical component (if any) – Nil

Essential Readings:

1. Fenton, N., & Neil, M. (2013). Risk assessment and decision analysis with bayesian networks. New York: CRC Press, Taylor and Francis Group.
2. Goodwin, Paul and Wright, George (2004). Decision Analysis for Management Judgement, 3rd edition, John Wiley & Sons Ltd.
3. Jensen, F. V., & Nielson, T. D. (2007). Bayesian networks and decision graphs (2nd ed.). New York: Springer Science.
4. Jones, J. M (1977). Introduction to decision theory, irwin series in quantitative analysis for business (1st ed.). New York: Irwin (Richard D.) Inc.
5. Levy, H. (2006). Stochastic dominance – investment decision making under uncertainty (2nd ed.). New York: Springer Science.
6. Parmigiani, G., & Inoue, L. (2009). Decision theory-principles and approaches. UK: John Wiley & Sons Ltd.
7. Sheskin, T. J. (2010). Markov chains and decision processes for engineers and managers. New York: CRC Press, Taylor and Francis Group.

Suggested Readings:

1. Smith, J. Q. (2010). Bayesian decision analysis-principles and practice. UK: Cambridge University Press.
2. Kaas, R., Goovarts, M., Dhaene, J., & Denuit, M. (2001). Modern actuarial risk theory. Netherlands: Kluwer Academic Publishers.

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DISCIPLINE SPECIFIC ELECTIVE
DSE-1(c): DESIGN THINKING AND INNOVATION

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Design Thinking and Innovation (DSE-1(c))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:
- To equip students with knowledge of design thinking process and its application in innovation.
- To equip students with the knowledge of different design thinking approaches and innovation management
- To impart knowledge of data analytics tools for innovation development, positioning and management.

Learning Outcomes:

Students completing this course will be able to:
- Understand the purpose of design thinking and its applications in innovation.
- Learn Design Thinking processes and approaches for ideation, concept development, evaluation, user feedback and iterative design thinking.
- Learn the role of data analytics in innovation development, positioning and management.

Syllabus of DSE 1(c):

Unit I: Introduction to Design Thinking and Innovation (11 hours)
Origin and Purpose of Design and Innovation, Fundamentals of Design Thinking, Design Thinking Process, Key Features of the Design Thinking Process, Cognitive Models for Design Thinking, Innovation and its Importance, Types of Innovation, Design Thinking for Innovation in Physical Products, in Digital Products, in Services, Products and its Levels, Finding Product Market Fit (PMF), Product Life Cycle.

Unit II: Design Thinking Approaches (12 hours)
Design Thinking Approach for Idea Generation: Problem Framing, Idea Generation, Creative & Critical Thinking, Brainstorming-Introduction, Examples, Principles and Process, Methods; Reverse Brainstorming. Design Thinking Approach for Concept Development: Innovation Idea Funnel, Concept Development- Introduction, Process, Tools; Product Concept ideation tools, Storyboard, Sketches and Wireframes, System Map. Design Thinking Approach for Concept Evaluation: Assumption Testing, Kano Model, Value / Ease Matrix, Rapid Prototyping. Design Thinking Approach for Obtaining User Feedback: Minimum Viable Product, Customer Co- Creation. Lifecycle Assessment and Environmental Impact Analysis.

Unit III: Design Thinking Approach for Innovation Development (11 hours)
Innovation, Sources of Innovative Ideas, Jeanne Liedtka's Framework for Design Thinking, Understanding Customers' Expectations, Maslow's Hierarchy of Needs, Types of Data Required to Gather Information Regarding Customers, Research Methods to Gather Customer Data, Value Chain Analysis, Mind Mapping, Value Proposition, Agile Methodologies in Design and Development.

Unit IV: Innovation Management (11 hours)
Data Analytics for Innovation: Customer Segmentation and Targeting, Data-driven Design Decision Making, Positioning and Differentiation Go-to-market Strategy, Adoption of Innovation, Innovation Adopters, Models of innovation adoption & management.

Tutorial component (if any) – Yes (15 hours)

Practical component (if any) – Nil

Essential Readings:

1. Christian Müller-Roterberg, (2018). Handbook of Design Thinking, Kindle Direct Publishing.
2. Gavin Ambrose, Paul Harris (2010). Basics Design: Design Thinking, AVA Publishing.
3. Tim Brown (2009). Change by design, 1st Ed., Harper Bollins.
4. Kelly Tom (2001). The Art of Innovation, Currency.
5. Christensen, Clayton M. (1997). The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail. Boston, MA: Harvard Business School Press.
6. Lilien, Gary.L, Kotler P.& Moorthy K. Sridhar (1998). Marketing Models, Prentice Hall India Learning Private Limited.

Suggested Readings:

1. Idris Mootee (2013). Design Thinking for Strategic Innovation: What They Can't Teach You at Business or Design School", John Wiley & Sons.
2. Maurício Vianna, Ysmar Vianna, Isabel K. Adler, Brenda Lucena, Beatriz Russo (2011). Design thinking: Business Innovation MJV Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE
DSE-1(d): GAME THEORY WITH BEHAVIORAL ASPECTS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Game Theory with Behavioral Aspects (DSE-1(d))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- To provide an in-depth exploration of game theory and its application to business and economics, including 2-persons and n-persons.
- To understand behavioral game theory, highlighting how psychological factors affect strategic decisions.

Learning Outcomes:

Students completing this course will be able to:

- Understand the basic concepts of game theory and its relevance to business and economics.
- Study famous games such as Prisoner's Dilemma, The Ultimatum Game, The Tragedy of the Commons, The Battle of the Sexes and The Stag Hunt.
- Analyse and develop core strategies for various types of games, including 2-persons and n- persons.
- Apply game-theoretic concepts to real-world problems in business, economics, and society.
- Use behavioral scenarios in strategic decision-making.

Syllabus of DSE-1(d):

Unit I: Foundations of Game Theory **(10 hours)**

Introduction to Game Theory: Overview of game theory, Importance and applications in business. Key concepts: players, strategies, payoffs, and value of the game. Non-cooperative Games: Examples of discrete and continuous static games involving two-persons and n- persons. Famous games: Prisoner's Dilemma, The Ultimatum Game, and The Tragedy of the Commons.

Unit II: **Zero-Sum Matrix Games** **(11 hours)**

Two-person zero-sum matrix game: Minimax and Maximin rules, convex and concave games, Dominant and dominated strategies. Solution of matrix games of size **2 x 2, 2 x n, m x 2, and m x n**.

Unit III: Nash Equilibrium and Game Theory Applications **(12 hours)**

Nash Equilibrium: Definition, properties, and significance. Computation of equilibria using optimality conditions. Solution of Bi-matrix and Symmetric matrix games. Game theory applications in advertising, strategic positioning, and oligopoly models, voting systems, bidding, and negotiation.

Unit IV: Cooperative Games and Behavioral Insights (12 hours)
Introduction to Cooperative Games. Solutions based on characteristic functions: The core and the Shapley values. Behavioral Game Theory: Bounded rationality, psychological aspects of decision-making, biases, fairness, reciprocity, and social preferences.

Tutorial component (if any) – Yes (15 hours)

Practical component (if any) - Nil

Essential Readings:

1. Mastumoto, A., & Szidarovszky, F. (2016). Game Theory and Its Applications. Springer.
2. Mazalov, V. (2014). Mathematical Game Theory and Applications. John Wiley & Sons, Inc.
3. Thie, P. R. & Keough, G. E. (2008). An Introduction to Linear Programming and Game Theory, John Wiley & Sons, Inc.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE
DSE-1(e): SIMULATION MODELING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Simulation Modeling (DSE-1(e))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- To provide detailed understanding of simulation concepts and its applications.
- To help students to design and analyse simulation models with its application on real world problems.

Learning Outcomes:

Students completing this course will be able to:

- Understand the fundamentals of simulation and model building.
- Apply different methods of random number generation to generate discrete and continuous random variable
- Conduct analysis of simulation models.
- Understand and apply principles of Monte Carlo simulation.
- Decode case studies to discover various simulation applications.

Syllabus of DSE-1(e):

Unit I: Fundamentals of Simulation and Modeling (12 hours)

Introduction to Simulation: concept of model and model building, Concept and terminologies of simulation, Process of simulation, Advantages and limitations of simulation, Classification of simulation models: physical and mathematical models, static and dynamic model, discrete and continuous models, deterministic and stochastic models. Application areas of simulation.

Unit II: Random Number Generation (11 hours)

Properties of random numbers, Generation of pseudo random numbers, Techniques of generating discrete and continuous random variables: inverse transformation, direct transformation, rejection method, hazard rate method. Test for random numbers.

Unit III: Design and Analysis of Simulation Models (12 hours)

Data collection, identifying distributions with data, Parameter estimation, Goodness of fit tests, selecting input models without data, Steady-state simulation, Terminating simulation, Confidence interval estimation, Output analysis for steady state simulation. Simulation run statistics, Replication of runs, Elimination of initial bias.

Unit IV: Monte Carlo Methods, Simulation Tools, and Applications (10 hours)
Monte Carlo simulation. Simulation tools: General-purpose simulation tools, Case studies of different types of simulation.

Tutorial component (if any) - Yes (15 hours)

Practical component (if any) - Nil

Essential Readings:

1. Ross, S., *Simulation*, Academic Press, 5th Edition 2012.
2. A.M. Law and W.D. Kelton, *Simulation and Modeling and analysis*, 5th Edition, 2015.
3. Evans, J. R., & Olson, D. L. *Introduction to simulation and risk analysis*. Prentice-Hall, Inc. 2nd Edition, 2001.
4. Geoffrey Gordon: *System Simulation*, 2nd Edition, 2002.
5. Frank L. Severance, *System Modeling and Simulation: An Introduction*, Wiley, 1st Edition, 2001.
6. J Banks, J. S. Carson II, B. L. Nelson, D. M. Nicol, 2010, Discrete Events System Simulation, 5th Edition, Prentice Hall.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE
DSE-1(f): SOFTWARE ENGINEERING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Software Engineering (DSE-1(f))	4	3	1	0	-	Nil

Learning Objectives:

The learning objectives of this course are as follows:

- To teach about the software development life cycle and related stages.
- To teach the concepts of software requirements analysis followed by design preparation.
- To teach various testing pedagogies available for software verification and validation.
- To teach how to quantitatively assess a software system's reliability by using different software reliability growth models.
- To teach about the software maintenance phenomenon.

Learning Outcomes:

Students completing this course will be able to:

- Understand the software development life cycle, its various stages, and different approaches for software development, such as the waterfall and evolutionary models.
- Know about recent advances in the software development process.
- Perform software requirements analysis, system design preparation.
- Understand Software Project management activities, including planning, scheduling, risk management, etc.
- Understand software testing approaches testing and integration testing, alpha and beta testing, System testing, Functional testing, Structural testing.
- Understand quality control and how to ensure good quality software.
- Develop and validate the mathematical models for in software reliability assessment and prediction.
- Understand the concept of multi-up-gradation for software maintenance.

Syllabus of DSE-1(f):

Unit I: Introduction to Software Engineering **(8 hours)**

Introduction to Software Engineering and related Principles, Software metrics and measurement, monitoring and control, Software development life-cycle Models: Software development life-cycle, Waterfall model, prototyping model, Incremental model, Iterative enhancement Model, Spiral model, Open Source Software and its life cycle.

Unit II: Stages of Software Development Process **(20 hours)**

Software Requirements: Analysis, Specification & Elicitation Techniques, requirements validation. System Design: Design Principles, Problem partitioning, abstraction, design specification, Cohesiveness and Coupling Software Project Management: Project planning, Software Metrics, Cost estimation using constructive cost models (Basic, Intermediate, and Detailed COCOMO), Risk management activities Software Testing**:** Verification and validation, code inspection, test plan, test case specification. Levels of testing: Unit, Integration Testing, Top-down and bottom-up integration testing, Alpha and Beta testing, System testing and debugging. Functional testing, Structural testing, Software testing strategies.

Unit III: Software Reliability **(10 hours)**

Modeling Software Reliability and its uses, Difference between hardware and software Reliability, Non-homogeneous Poisson Process models, Imperfect Debugging models, testing effort-based modeling, the concept of change point, Release Time problems based on Cost Criterion, Reliability Criterion, Cost and Reliability Criteria, Reliability of modular software, Resource Allocation Problem

Unit IV: Software Quality Assurance & Maintenance **(7 hours)**

Software quality, ISO 9000 certification for the software industry, SEI capability maturity model, Software implementation and integration, Software Maintenance models through multi- up-gradation concept.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Aggarwal, K. K., & Singh Y. (2005). Software engineering, New Age International.
2. Kapur, P., Pham, H., Gupta, A., & Jha, P. C. (2011). Software reliability assessment with OR applications. London: Springer-Verlag.
3. Pressman, R. S. (2005). Software engineering: a practitioner's approach. Palgrave Macmillan.
4. Wang, H., & Pham, H. (2010). Reliability and optimal maintenance. London: Springer- Verlag.
5. Yamada, S. (2014). Software reliability modeling: fundamentals and applications. Tokyo: Springer.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Skill Enhancement Course – Semester I

SEC - 1: Database Management System

SKILL ENHANCEMENT COURSE
SEC-1: DATABASE MANAGEMENT SYSTEM

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Database Management System (SEC-1)	**2**	**1**	**0**	**1**	**-**	**Nil**

Learning Objectives:

- The objective of the course is to present an introduction to Database Management Systems (DBMS), emphasizing how to organize, maintain, and retrieve information efficiently and effectively from a DBMS.
- The course shall provide a technical overview of database management systems, enabling the students to understand the logical design of the database using data modeling concepts and thereby manipulating any database using SQL.

Learning Outcomes:

Students completing this course will be able to:

- Describe the fundamental elements of relational database management systems.
- Utilize a wide range of features available in a DBMS package.
- Analyze database requirements and determine the entities involved in the system and their relationship to one another.
- Develop the logical design of the database using data modeling concepts.
- Manipulate a database using SQL.

Syllabus of SEC-1:

Unit I: Introduction to Databases and basics of SQL (5 Theory hours + 10 Practical hours)

Database Management System- Introduction, concepts and architecture, Characteristics, Advantages of Using DBMS, Brief History of Database Application, Data Models, Schemas, Instances, Three-Schema Architecture and Data Independence, Database Languages and Interfaces, Classification of Database Management Systems. DDL commands in SQL-Table creation, alteration, defining constraints – Primary key, foreign key, unique, not null, check,

Unit II: Relational Algebra, Data Modeling and Database Design

(5 Theory hours + 5 Practical hours)

Structure of Relational databases, Domains, Relations, Relational Algebra and related queries, relational calculus, Entity Types, Entity Sets, Attributes, and Keys; Relationships and Participation; Codd's Rules; ER Diagrams and Schema; EER Model; Relational Model Concepts; Functional Dependencies; Normalization (1NF, 2NF, 3NF, BCNF).

Unit III: Structured Query Language (2 Theory hours + 15 Practical hours)
SQL Commands: DML-update, delete, select – all columns, specific columns, unique records, conditional select, in clause, between clause, limit, aggregate functions (count, min, max, avg,sum), DQL, DCL, and TCL, group by clause, having clause. Use of group by, having, order by, join and its types, String Functions, Math Functions and Date Functions in SQL, set operations, sub queries, correlated sub-queries.

Unit IV: Transaction Management and Query Optimization (3 Theory hours)
Transaction Concepts; Transaction States; Properties of a Transaction; Concurrency Control; Disk Storage; RAID; Query Processing and Optimization; Distributed Databases.

Practical component (if any):

Students shall indulge in performing Practical in Computer Lab on SQL according to the above theory syllabus.

Essential Readings:

1. Dasai, B.C. (1998). Database System, BPB.
2. Date, C. J. (2006). An introduction to database systems. Pearson Education India.
3. Elmasri, R., & Navathe, S. (2011). Fundamentals of database systems (6th ed.), Addison- Wesley Publishing Company.
4. Ramakrishnan, R., & Gehrke, J. (2000). Database management systems. McGraw Hill. Schneider, D. I. (2013). An introduction to programming using visual basic 2012. Prentice Hall Press.
5. Silberschatz, A., Korth, H. F., & Sudarshan, S. (1997). Database system concepts (Vol. 4). New York: McGraw-Hill.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Generic Elective - Semester I

GE - 1(a): Inventory Management

GE - 1(b): Linear Programming & Extensions

GE - 1(c): Game Theory with Behavioral Aspects

GE - 1(d): Simulation Modeling

Department of Operational Research, University of Delhi

GENERIC ELECTIVE
GE-1(a): INVENTORY MANAGEMENT

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Prerequisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Inventory Management (GE-1(a))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- To impart knowledge of the role of inventory in organizations and core concepts of inventory management with an understanding of fundamental inventory control procedures and their usage.
- To provide students with a thorough understanding of basic inventory models and a rigorous mathematical framework to develop mathematical models to analyze and optimize inventory systems.
- To provide the students with a comprehensive study of various application areas of inventory models through case studies and relevant examples.

Learning Outcomes:

Students completing this course will be able to:

- Identify the goals and objectives of inventory management and describe the importance of stocks in an organization and the reasons for holding stock.
- Explain the various costs related to the inventory system.
- Understand the various selective inventory control techniques and their applications.
- Capability to develop deterministic inventory models: economic order quantity and its extensions, All units and incremental quantity discounts models, Joint and Individual order policies, and Production scheduling models.
- Understand and develop stochastic inventory models and setting safety stocks. Apply and extend inventory models to analyse real-world systems.

Syllabus of GE-1(a):

Unit I: Introduction to Inventory Systems **(9 hours)**

Analytical structure of Production and Inventory problems. Objectives of Inventory Management. Factors influencing inventories. Inventory-related costs. Properties of Inventory systems. Selective Inventory control techniques and their applications. Concept of Lead Time. Introduction to Just in Time (JIT) and Vendor Managed Inventory (VMI).

Unit II: Deterministic Inventory Models **(15 hours)**

Deterministic inventory models, economic order quantity and its extensions: without and with lead time. Finite replenishment rate Inventory models without and with planned shortages. Inventory models with partial backlogging and lost sales. Discrete Demand Model. Multi-item Inventory models with constraints. Quantity discounts: All units and incremental. Joint and Individual Ordering Policies.

Unit III: Production Planning Models **(9 hours)**

Aggregate Production Planning Models: Fixed workforce model. Variable workforce model. Dynamic lot size models: Wagner-Whitin Algorithm, Silver-Meal heuristic.

Unit IV: Stochastic Inventory Models **(12 hours)**

Stochastic Inventory models, Newsvendor model and its extensions: Instantaneous and uniform demand with discrete and continuous cases; without and with lead time. Transformations for the equivalence of instantaneous and uniform demand models. Power demand pattern inventory model. Periodic review models. Safety stocks, Service levels and reorder level.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Axsäter, S. (2015). *Inventory Control.* (Third Edition). Springer.
2. Hadley, G., & Whitin, T. M. (1963). *Analysis of Inventory Systems*. Prentice-Hall.
3. Johnson, L.A., & Montgomery, D.C. (1974) *Operations Research in Production Planning, Scheduling and Inventory Control*. Wiley, New York.
4. Muckstadt, J. A., & Sapra, A. (2010). *Principles of Inventory Management: When You Are Down to Four, Order More*. Springer Science & Business Media.
5. Naddor, E. (1966). *Inventory Systems*. Wiley.
6. Silver, E. A., Pyke, D. F., & Peterson, R. (1998). *Inventory Management and Production Planning and Scheduling*. (Third Edition). Wiley.
7. Waters, D. (2008). *Inventory Control and Management.* (Second Edition). John Wiley & Sons.
8. Zipkin, H. P. (2000). *Foundations of Inventory Management*. McGraw-Hill.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE
GE-1(b): LINEAR PROGRAMMING AND EXTENSIONS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Linear Programming and Extensions (GE-1(b))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- To impart knowledge of formulating practical problems using the linear programming method and its extensions.
- To understand the theoretical basics of different computational algorithms for solving linear programming and related problems.

Learning Outcomes:

Students completing this course will be able to:

- Describe the basic concepts of convex analysis and explain the theoretical foundations of various issues related to linear programming modelling.
- Formulate real-world problems as a linear programming model and describe the theoretical workings of the graphical and simplex methods.
- To solve linear programming problems using advanced simplex methods.
- Explain the relationship between a linear program and its dual, including weak and strong duality, complementary slackness, and sensitivity analysis.
- Formulate specialized linear programming problems, namely transportation, transshipment, and assignment problems, and describe the theoretical workings of the solution methods.

Syllabus of GE-1(b):

Unit I: Foundations of Linear Programming **(10 hours)**

Theoretical Foundations: Linear independence and dependence of vectors, Basis, Convex sets, Extreme points, Hyperplanes and half spaces, Polyhedral sets and cones. Results based on the above concepts. Introduction to Linear Programming. Problem formulations from different industries.

Unit II: **Simplex Method and Duality** **(13 hours)**

Theory of simplex method. Simplex method, including The Big M and Two-Phase methods. Degeneracy in Simplex Method. Definition and importance of duality. Formulating dual problems. Economic interpretation of duality. Weak and strong duality results. Complementary slackness.

Unit III: **Advanced Simplex Methods, Sensitivity Analysis and Transportation Problem** **(12 hours)**

Advanced Simplex Methods: Revised simplex method, Dual-simplex method. Sensitivity analysis for Structural and Parameter changes. Transportation problem: Mathematical model, Balanced and unbalanced problems. Degeneracy. Optimality conditions. Methods to find initial and optimal solutions.

Unit IV: **Transshipment and Assignment Problems** **(10 hours)**

Transshipment Problem: Extension of transportation problem to transshipment model, Formulation and solution. Assignment problem: Mathematical model, Balanced and unbalanced problems. Optimality conditions. Hungarian method for optimal assignment.

Tutorial component (if any) – Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Bazaraa, M. S., Jarvis, J. J., & Sherali, H. D. (2010). Linear Programming and Network Flows. John Wiley & Sons, Inc.
2. Chandra, S., Jayadeva, & Mehra, A. (2009). Numerical Optimization with Applications. New Delhi: Narosa Publishing House.
3. Hillier, F.S., Lieberman, G. J., & Nag, B. (2021). Introduction to Operations Research, (11th ed.). New Delhi: Tata McGraw Hill (Indian print).
4. Taha, H. A. (2019). Operations Research: An Introduction (10th ed.). New Delhi: Pearson (Indian print).

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE
GE-1(c): GAME THEORY WITH BEHAVIORAL ASPECTS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Game Theory with Behavioral Aspects (GE-1(c))	4	3	1	0	-	Nil

Learning Objectives:

The learning objectives of this course are as follows:

- To provide an in-depth exploration of game theory and its application to business and economics, including 2-persons and n-persons.
- To understand behavioral game theory, highlighting how psychological factors affect strategic decisions.

Learning Outcomes:

Students completing this course will be able to:

- Understand the basic concepts of game theory and its relevance to business and economics.
- Study famous games such as Prisoner's Dilemma, The Ultimatum Game, The Tragedy of the Commons, The Battle of the Sexes and The Stag Hunt.
- Analyse and develop core strategies for various types of games, including 2-persons and n- persons.
- Apply game-theoretic concepts to real-world problems in business, economics, and society.
- Use behavioral scenarios in strategic decision-making.

Syllabus of GE-1(c):

Unit I: Foundations of Game Theory **(10 hours)**

Introduction to Game Theory: Overview of game theory, Importance and applications in business. Key concepts: players, strategies, payoffs, and value of the game. Non-cooperative Games: Examples of discrete and continuous static games involving two-persons and n- persons. Famous games: Prisoner's Dilemma, The Ultimatum Game, and The Tragedy of the Commons.

Unit II: **Zero-Sum Matrix Games** **(11 hours)**

Two-person zero-sum matrix game: Minimax and Maximin rules, convex and concave games, Dominant and dominated strategies. Solution of matrix games of size **2 x 2, 2 x n, m x 2, and m x n**.

Unit III: Nash Equilibrium and Game Theory Applications **(12 hours)**

Nash Equilibrium: Definition, properties, and significance. Computation of equilibria using optimality conditions. Solution of Bi-matrix and Symmetric matrix games. Game theory applications in advertising, strategic positioning, and oligopoly models, voting systems, bidding, and negotiation.

Unit IV: Cooperative Games and Behavioral Insights (12 hours)
Introduction to Cooperative Games. Solutions based on characteristic functions: The core and the Shapley values. Behavioral Game Theory: Bounded rationality, psychological aspects of decision-making, biases, fairness, reciprocity, and social preferences.

Tutorial component (if any) – Yes (15 hours)

Practical component (if any) - Nil

Essential Readings:

1. Mastumoto, A., & Szidarovszky, F. (2016). Game Theory and Its Applications. Springer.
2. Mazalov, V. (2014). Mathematical Game Theory and Applications. John Wiley & Sons, Inc.
3. Thie, P. R. & Keough, G. E. (2008). An Introduction to Linear Programming and Game Theory, John Wiley & Sons, Inc.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE
GE-1(d): SIMULATION MODELING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Simulation Modeling (GE-1(d))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- To provide detailed understanding of simulation concepts and its applications.
- To help students to design and analyse simulation models with its application on real world problems.

Learning Outcomes:

Students completing this course will be able to:

- Understand the fundamentals of simulation and model building.
- Apply different methods of random number generation to generate discrete and continuous random variable
- Conduct analysis of simulation models.
- Understand and apply principles of Monte Carlo simulation.
- Decode case studies to discover various simulation applications.

Syllabus of GE-1(d):

Unit I: Fundamentals of Simulation and Modeling (12 hours)

Introduction to Simulation: concept of model and model building, Concept and terminologies of simulation, Process of simulation, Advantages and limitations of simulation, Classification of simulation models: physical and mathematical models, static and dynamic model, discrete and continuous models, deterministic and stochastic models. Application areas of simulation.

Unit II: Random Number Generation (11 hours)

Properties of random numbers, Generation of pseudo random numbers, Techniques of generating discrete and continuous random variables: inverse transformation, direct transformation, rejection method, hazard rate method. Test for random numbers.

Unit III: Design and Analysis of Simulation Models (12 hours)

Data collection, identifying distributions with data, Parameter estimation, Goodness of fit tests, selecting input models without data, Steady-state simulation, Terminating simulation, Confidence interval estimation, Output analysis for steady state simulation. Simulation run statistics, Replication of runs, Elimination of initial bias.

Unit IV: Monte Carlo Methods, Simulation Tools, and Applications (10 hours)
Monte Carlo simulation. Simulation tools: General-purpose simulation tools, Case studies of different types of simulation.

Tutorial component (if any) - Yes (15 hours)

Practical component (if any) - Nil

Essential Readings:

1. Ross, S., *Simulation*, Academic Press, 5th Edition 2012.
2. A.M. Law and W.D. Kelton, *Simulation and Modeling and analysis*, 5th Edition, 2015.
3. Evans, J. R., & Olson, D. L. *Introduction to simulation and risk analysis*. Prentice-Hall, Inc. 2nd Edition, 2001.
4. Geoffrey Gordon: *System Simulation*, 2nd Edition, 2002.
5. Frank L. Severance, *System Modeling and Simulation: An Introduction*, Wiley, 1st Edition, 2001.
6. J Banks, J. S. Carson II, B. L. Nelson, D. M. Nicol, 2010, Discrete Events System Simulation, 5th Edition, Prentice Hall.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Discipline Specific Core - Semester II

DSC - 4: Optimization Techniques

DSC - 5: Queueing Theory

DSC - 6: Python Programming for Decision-Making

DISCIPLINE SPECIFIC CORE
DSC-4: OPTIMIZATION TECHNIQUES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Optimization Techniques (DSC-4)	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- To comprehensively understand optimization techniques and their applications in science, engineering, economics, and management.
- To analyze and apply nonlinear optimization, integer linear, and linear goal programming methods to complex decision-making situations in diverse fields.

Learning Outcomes:

Students completing this course will be able to:

- Explain the concepts of convex functions and their properties and describe the convex optimization problem.
- Describe the optimality conditions for unconstrained and constrained optimization problems.
- Demonstrate the formulations of real-world situations as integer linear programming problems and describe the theoretical workings of the solution methods.
- Demonstrate the formulations of real-world situations as quadratic programming problems and describe the theoretical workings of the solution methods.
- Demonstrate the formulations of real-world situations as linear goal programming problems and describe the theoretical workings of the solution methods.

Syllabus of DSC-4:

Unit I: Unconstrained Optimization and Convex Functions (10 hours)
Unconstrained optimization problems: Local and global extrema, necessary and sufficient optimality conditions, line search method, and gradient descent method. Introduction to Convex Functions. Properties of Convex Functions. Applications in Optimization.

Unit II: **Constrained Optimization: Optimality, Duality and Methods (12 hours)**
Constrained optimization problems: Lagrange multipliers, Karush-Kuhn-Tucker optimality conditions. Wolfe Dual. Weak and strong duality results. Quadratic Programming: Wolfe method, sequential linear programming (Frank-Wolfe) method and reduced gradient method.

Unit III: Integer Linear Programming: Concepts and Methods (12 hours)
Introduction to Integer linear programming. Modelling pure and mixed integer linear programming for real-world problems, including manufacturing, logistics, finance, telecommunication, and scheduling. Solution techniques: Branch and bound. Gomory's cutting plane algorithm. 0-1 programming problem. E-Bala's additive algorithm.

Unit IV: Goal Programming: Concepts and Methods (11 hours)
Introduction to Goal Programming. Types of goal programming: linear goal programming, Archimedean goal programming, and Preemptive goal programming. Solution techniques: Graphical method and Lexicographic Simplex method. Real-world modelling applications using linear goal programming in manufacturing, logistics, finance, telecommunications, and scheduling.

Tutorial component (if any) – Yes (15 hours)

Practical component (if any) - Nil

Essential Readings:

1. Antoniou, A., & Lu, Wu-Sheng (2021). Practical Optimization: Algorithms and Engineering Applications (2nd ed.). Springer.
2. Bazaraa, M. S., Sherali, H. D., & Shetty, C. M. (2006). Nonlinear programming; Theory and Algorithms (3rd ed.). John Wiley & Sons, Inc.
3. Chandra, S., Jayadeva, & Mehra, A. (2009). Numerical Optimization with Applications, Narosa Publishing House.
4. Hillier, F.S., Lieberman, G. J., & Nag, B. (2021). Introduction to Operations Research (11th ed.). Tata McGraw Hill.
5. Taha, H. A. (2019). Operations Research: An Introduction (10th ed.). Pearson.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE
DSC-5: QUEUEING THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Queueing Theory (DSC-5)	4	3	1	0	-	Nil

Learning Objectives:

The learning objectives of this course are as follows:

- To impart knowledge of queueing theory and provide the students with a rigorous framework which would enable them to model and analyze queueing systems.
- To provide the students necessary mathematical support and confidence to the students to tackle real life problems.
- To explore both theory and application of fundamental and advanced models in this field.

Learning Outcomes:

Students completing this course will be able to:

- Gain a deep understanding of the theoretical background of queueing systems.
- Understand and compute quantitative metrics of performance for queueing systems.
- Apply and extend queueing models to analyze real world systems.

Syllabus of DSC-5:

Unit I: Introduction **(10 hours)**

Basic Concepts of Stochastic Process, Markov Chains, Introduction to Queueing Systems, Characteristics of Queueing Systems, Counting Process, Poisson Process (Pure-Birth Process and Pure-Death Process), Expected Measures of System Performance, Queueing Simulation: Data Generation and Book-Keeping.

Unit II: Markovian Queueing Models **(15 hours)**

General Birth-Death Process, Infinite Capacity Queues: Single-Server Queues (M/M/1) and Multi-Server Queues (M/M/c), Finite Capacity Queues: M/M/1/K, M/M/c/K and M/M/c/c (Erlang's Loss System), Queues with Unlimited Service (M/M/∞), Finite-Source Queues, Queues with State-Dependent Service, Queues with Impatience (M/M/1 Balking and M/M/1 Reneging).

Unit III: Advanced Markovian Queueing Models **(15 hours)**

Queues with Bulk Arrival ($M^{[X]}/M/1$), Queues with Bulk Service ($M/M^{[Y]}/1$), Erlangian Queueing Models ($M/E_k/1$ and $E_k/M/1$), Concept of Imbedded Markov Chains, Queues with General Arrivals (G/M/1), Queues with General Service (M/G/1).

Unit IV: Decision Problems in Queueing Systems **(5 hours)**

Design and Control Problems in Queueing Systems, Queueing System with Server Vacation, Queueing System with Removable Server.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Bhat, U. N. (2015). An introduction to Queueing Theory: Modelling and Analysis in Applications (Statistics for Industry and Technology) (2nd Edition). Birkhauser Boston.
2. Cooper, R.B. (1981). Introduction to Queueing Theory (2nd Edition). Elsevier North Holland.
3. Cox, D. R. and Smith, W. L. (1991). Queues. Chapman and Hall/CRC.
4. Gross, Donald, Shortle , John F., Thompson, James M., and Harris, Carl M. (2018). Fundamentals of Queueing Theory (5th Edition), John Wiley and Sons Inc. Pte. Ltd.
5. Kleinrock L. (1975). Queueing Systems, Volume 1: Theory, John Wiley.
6. Medhi, J. (2003). Stochastic Models in Queueing Theory (2nd Edition), Academic Press.
7. Prabhu, N. U. (2012). Foundations of Queueing Theory (International Series in Operations Research & Management Science), Springer (Softcover reprint of the original 1st ed. 1997 edition.)
8. Satty, T. L. (1983). Elements of Queueing Theory with Applications, Dover Publications, NY. (Reprint Edition)

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE
DSC-6: PYTHON PROGRAMMING FOR DECISION-MAKING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Python Programming for Decision-Making (DSC-6)	**4**	**3**	**0**	**1**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- To introduce the basic concepts of Python programming required for data science.
- To teach the students about Python's ability to handle different data formats such as numbers, strings, lists, dictionaries, sets, tuples, etc.
- The students will be made familiar with the concepts of loops, modularization of code using built-in functions and user-defined functions will also be explained.
- Introduce the basics of various useful libraries to equip the students with modern computing skills.

Learning Outcomes:

Students completing this course will be able to:

- Learn Python installation, configuration and understand scripting using python.
- Understand different data types and arithmetical, logical and relational expressions in Python.
- Understand the control structures and functions in Python and handle simple data structures, lists, dictionaries, sets and tuples and modularize the code using built-in functions and user- defined functions.
- Implement Object Oriented Programming concepts in Python
- Write clean and efficient Python code for data analysis and build pipelines from raw data to insights.
- Visualize and communicate data findings.
- Understand the concept of various algorithms and work on real-world projects.

Syllabus of DSC-6:

Unit I: Introduction to Python Programming **(11 hours)**

Familiarization with the basics of Python programming, interactive mode, and script mode, Structure of a Program, process of writing a program, script execution, and debugging errors. Identifiers, Keywords, Constants, Variables, and data types. Arithmetic operators, Relational operators, Logical operators, Ternary operators, and Bitwise operators. Input and Output Statements, Control Structures. Introduction to functions: modules, built-in and user-defined functions: impeding modules, invoking built-in functions. User-defined functions: Parameters, scope of variables, passing parameters, void functions, and functions returning values.

Unit II: Data Structures (Strings, Lists, Tuples and Dictionary) (11 hours)
Strings: initializing strings and accessing the elements, string operations, built-in string functions, and methods. Lists: concepts of mutable lists; List operations: creating, initializing, accessing, traversing, appending/inserting, searching, and deleting elements; list functions (inbuilt and user-defined). Tuples: Concepts of immutable, creating, initializing, accessing elements; tuple assignment, slices, and indexing; tuple functions. Dictionary: Concept of key- value pair, creating, initializing, accessing, traversing, appending, updating and deleting elements; dictionary functions and methods.

Unit III: Object Orientation in Python (9 hours)
Creation of instance variables in Python, self-keyword in Python, static and non-static methods in Python, OOPS concept (Encapsulation, polymorphism, Abstraction, Inheritance), concept of Classes, Exception handling.

Unit IV: Advanced Python Concepts (14 hours)
Working with libraries: Pandas, NumPy, Matplotlib, and Sci-kit learn; Pandas: Working with Data Frame, importing from csv files, Numpy: Array and Matrix Operations, Matplotlib: Plotting graphs for various mathematical and statistical functions, Sci-kit learn: Data Pre-processing, Curve Fitting and Regression—Python libraries for Optimization: SciPy and PuLP.

Practical component (if any): Yes (30 hours)

Students shall indulge in performing Practical in Computer Lab on Python Software according to the above theory syllabus.

1. Write a program to enter name and display as “Hello, Name”.
2. Write a menu driven program to enter two numbers and print the arithmetic operations like
   a. + b. – c. * d. / e. // f. %.
3. Write a program to compute the roots of a quadratic equation.
4. Write a menu driven program to reverse the entered numbers and print the sum of digits entered.
5. Write a menu driven program to enter the number and print whether the number is odd or even prime.
6. Write a program to find maximum out of entered 3 numbers
7. Write a program to display ASCII code of a character and vice versa.
8. Write a program to check if the entered number is Armstrong or not.
9. Write a program to find factorial of the entered number using recursion.
10. Write a program to enter the number of terms and to print the Fibonacci Series.
11. Write a program to enter the numbers and to print greatest number using loop.
12. Write a program to enter the string and to check if it’s palindrome or not using loop.
13. Write a program to enter the 5 subjects’ numbers and print the grades A/B/C/D/E.
14. Write a program in python language to display the given pattern:

15. Write a python function sin (x, n) to calculate the value of sin(x) using its Taylor series expansion up to n terms.

$$\sin(x) = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \cdots,$$

16. Write a program to determine EOQ using various inventory models.
17. Write a program to determine different characteristics using various queuing models.
18. Write a program to implement Inheritance. Create a class Employee inherit two classes Manager and Clerk from Employee.
19. Write a program to fit Poisson distribution on a given data.
20. Write a program to implement linear regression using python.
21. Write a program to perform read and write operation with .csv file.
22. Write a program to enter multiple values-based data in multiple columns/rows and show that data in Python using DataFrames and pandas.
23. Write a program in python to perform various statistical measures using pandas.
24. Write a program to plot a bar chart in python to display the result of a school for five consecutive years.
25. Write a program in python to plot a graph for the function $y = x^2$
26. Write programs related to creating and modifying List, Tuple and Dictionary.
27. Write programs to find correlation between dependent and independent variables.
28. Write programs for data visualization (Charts using plot () function, Pie Chart, Scatter Plot, Histogram, Bar Chart).
29. Write programs making use of PuLp library.
30. Write programs making use of Scipy.

Essential Readings:

1. Deitel, P. J. (2019). Python Fundamentals. Pearson.
2. Dierbach, C. (2012). Introduction to computer science using python: a computational problem-solving focus. Wiley Publishing.
3. Guttag, J. V. (2013). Introduction to computation and programming using Python. MIT Press.
4. Lambert, K. A. (2018). Fundamentals of python: first programs. Cengage Learning.
5. Lutz, M., & Lutz, M. (1996). Programming python (volume 8). O'Reilly Media, Inc.
6. Thareja, R. (2017). Python programming using problem solving approach. Oxford University Press.
7. VanderPlas, J. (2016). Python data science handbook: essential tools for working with data. O'Reilly Media, Inc.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Discipline Specific Elective – Semester II

DSE - 2(a): Applied Multivariate Analysis

DSE - 2(b): Financial Management

DSE - 2(c): Fundamentals of Managerial Economics

DSE - 2(d): Marketing Research

DSE - 2(e): Quality Management

DSE - 2(f): Soft Computing

DISCIPLINE SPECIFIC ELECTIVE
DSE-2(a): APPLIED MULTIVARIATE ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Applied Multivariate Analysis (DSE - 2(a))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:
- Understand the theoretical foundations of multivariate statistical methods.
- To teach the application of data reduction techniques such as Principal Component Analysis (PCA) and Factor Analysis.
- To teach about classification methods, including Discriminant Analysis and Logistic Regression.
- Fit and interpret Multivariate Regression Models and Canonical Correlation Analysis.
- Visualize and interpret multivariate data using appropriate methods.

Learning Outcomes:

Students completing this course will be able to:
- Understand the role of multivariate techniques in strategic decision-making
- Have an understanding of statistical methods to analyse datasets with multiple variables simultaneously.
- Choose appropriate multivariate methods based on the research question.
- Create Interpretation of multivariate analysis results in a practical context.
- Understand different statistical data analysis techniques that are used for managerial decisions
- Apply Multivariate techniques in marketing, finance, healthcare, and social sciences.
- Have an understanding of Model selection and validation on real-world datasets.
- Make data-driven decisions from multivariate analysis.

Syllabus of DSE-2(a):

Unit I: Introduction to Multivariate Techniques **(9 hours)**
Range of Multivariate techniques available, selecting a multivariate technique, Use of Multivariate analysis methods across a range of industries and in Research & development.

Unit II: **Dependency Techniques** **(9 hours)**
Multiple Linear Regression Models, Logistic Regression & Receiver Operating Characteristic (ROC) curve, Discriminant Analysis.

Unit III: Interdependency Techniques **(13 hours)**
Correspondence Analysis, Conjoint Analysis, Chi-square Automatic Interaction Detector (CHAID) Analysis, Interpretive Structural Modeling (ISM), Matriced' Impacts Croise's Multiplication Appliquée a UN Classement (MICMAC) analysis. Exploratory and Confirmatory Factor Analysis, Application of the Henry Garrett Technique and other related interdependent techniques.

Unit IV: Some Assessment Techniques for Managerial Discretion **(14 hours)**
Application of Multi-Attribute Utility Theory, Two-way Assessment Methods, Understanding the importance of Normalization and some ranking techniques for managerial decision making**,** The Kano Model (to explore and measure customer needs), and Introduction to Market Basket Analysis.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Tzeng, G.H, Huang, J.J, (2011). Multiple Attribute Decision making Methods and Applications. CRC Press, Taylor & Francis Group
2. Backhaus, K., Erichson, B., Gensler, S., Weiber, R., & Weiber, T. (2021). Multivariate analysis. Springer Books, 10(1), 973-8.
3. Johnson, Richard A.; Wichern, Dean W. (2007). Applied Multivariate Statistical Analysis (Sixth ed.). Prentice Hall.
4. Johnson R A; Wichern D, (2002). Applied Multivariate Statistical Analysis: Prentice-Hall, New Jersey.
5. Johnson, D. E. (1998). Applied Multivariate Methods for Data Analysts: Duxbury Press.

Suggested Readings:

1. Sheth, J. N. (2011). What is Multivariate Analysis?. Marketing Classics Press.
2. Sharma, S. (1996) Applied Multivariate Techniques. Wiley

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE
DSE-2(b): FINANCIAL MANAGEMENT

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Financial Management (DSE-2(b))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

- This introductory course in financial management focuses on the practical aspects of corporate finance.
- The course emphasizes understanding of financial management and working knowledge of the financial environment in which the firm operates to develop appropriate financial strategies.
- The course also covers the application of optimization techniques to financial management problems.

Learning Outcomes:

Students completing this course will be able to:

- Identify the objective of the firm's managerial finance role and outline the implications of the separation of ownership and control.
- Evaluate financial statements using ratio analysis and apply various techniques based on the time value of money. Explain general concepts of valuing financial assets and calculate the value of debt and equity securities.
- Understand the risk-return trade-off and demonstrate risk measurement through the Capital Asset Pricing Model (CAPM).
- Apply various capital budgeting techniques and calculate the weighted average cost of capital (WACC).
- Outline alternative sources of long-term funds and contrast operating leverage and financial leverage. Identify appropriate Operational Research techniques for financial decision making.

Syllabus of DSE-2(b):

Unit I: Introduction to Financial Management **(14 hours)**

Meaning, nature and scope of financial management. Financial markets. Financial Management goal: profit vs. wealth maximization. Finance functions: investment, financing and dividend decisions. Time Value of Money: Future and Present Value; Ordinary Annuity, Annuity Due and Perpetuity, Effective Annual Interest Rate (EAR), Loan Amortization. Valuation of Securities: Bonds and their Valuation, Bond Yields. Common and Preferred Stocks and their Valuation. Relationship (Trade-off) between risk and return, Capital Asset pricing model. Financial Statements: Balance Sheet, Income Statement, Statement of Cash Flows. Analysis of Financial Statements: Ratio Analysis, Du Pont Equations. Financial Planning and Forecasting: percentage of sales method, AFN Equation, cash budget.

Unit II: Capital Budgeting **(10 hours)**

Capital Budgeting process, Project Selection. Estimation of project cash flows, Capital Budgeting Techniques: Payback Period Methods, Average rate of return, Net Present Value methods, IRR, Benefit-Cost ratio, Capital rationing. Cost of Capital: Meaning and significance of cost of capital, Cost of debt, Cost of Equity and reserves, Cost of preferred stock, weighted average cost of capital, Factors affecting cost of capital.

Unit III: Operating and Financial Leverage **(10 hours)**

Measurement of leverages; Effects of operating and financial leverage on profit, analyzing alternate financial Plans, combined leverage. Capital Structure: Introduction, Factors affecting capital structure, Features of an optimal capital structure, Miller Modigliani propositions I and
II. Dividend policy: Aspects of dividend policy, practical consideration, forms of dividend policy, share splits.

Unit IV: Working Capital Management **(11 hours)**

Concepts, needs, Determinants, issues and estimation of working capital, Accounts Receivables Management, Inventory management, Cash management. Financing of working capital, Source of working capital: Spontaneous Source and Negotiable Source, Types of bank finance: commercial papers, other sources. Analytical approach to finance: Application of Operational Research techniques to the problems in Financial Decision Making.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Brealey, R., Myres, S., Franklin, A., Edmans, A., & Mohanty, P. (2023). Principles of Corporate Finance (14th ed.). McGraw Hill (India).
2. Brigham, E. F., & Michael, C.E. (2017). Financial Management- Theory and Practice (15th ed.). Cengage (India).
3. Cornuejols, G., Peña, J., & Tütüncü, R. (2018). Optimization methods in finance. Cambridge University Press.
4. Keown, A. J., Martin, J. D., & Petty, J. W. (2020). Foundations of finance (10th ed.). New Jersey: Pearson.
5. Khan, M. Y., & Jain, P. K. (2018). Financial Management: Text, Problems and Cases (8th ed.). McGraw Hill (India).
6. Spronk, J. (1981). Interactive Multiple Goal Programming: Applications to Financial Planning. Martinus Nijhoff Publishing.
7. Van Horne, J. C., & Wachowicz, J. M. (2008). Fundamentals of Financial Management (13th ed.). Harlow: Prentice Hall Inc.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE
DSE-2(c): FUNDAMENTALS OF MANAGERIAL ECONOMICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Fundamentals of Managerial Economics (DSE-2(c))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- To familiarize students with the fundamental concepts and theories of Managerial Economics.
- To strengthen managerial decision-making skills in today's competitive environment.
- The course also covers the application of optimization techniques to managerial decision making.

Learning Outcomes:

Students completing this course will be able to:

- Develop an understanding of basic concepts and issues in Managerial Economics and their applications in business decisions.
- Apply theories and tools covered under economics for analyzing business environment.
- Identify different economic factors and their importance in managerial decision making.
- Understand, evaluate and forecast demand and production functions in economics.
- Design competitive strategies according to the market structure.
- Enhance their knowledge of how markets operate and the capability in making economic predictions about markets.
- Identify appropriate optimization techniques for managerial decision making.

Syllabus DSE-2(c):

Unit I: Introduction to Managerial Economics **(8 hours)**

Objectives and features of managerial economics, Scope and importance of managerial economics, Goals of managerial decisions, Managerial decision making as optimizing with constraints, Marginal analysis in decision making. Formulation of relationships among economic variables using regression analysis. Basic optimization techniques for economic analysis.

Unit II: Demand and Supply Analysis **(15 hours)**

Theory of Demand: determinants of demand; law of demand; price elasticity of demand; income elasticity of demand; cross-price elasticity of demand; demand forecasting, theory of consumer behavior, Preference, Utility functions, Indifference curve. Supply Analysis: determinants of supply; law of supply; elasticity of supply, Market equilibrium: determination of equilibrium price and quantity.

Unit III: Production and Cost Analysis **(11 hours)**

Theory of production: factors of production; production function; law of variable proportions; returns to scale, Profit maximization: Constrained optimization approach. Cost Analysis: concept of costs; short-run and long-run costs; average and marginal costs; total, fixed and variable costs.

Unit IV: Market Structure and Pricing Practices **(11 hours)**

Market Structure: Different forms of markets - Perfect competition, Duopoly, Monopoly, Monopolistic competition, Oligopoly. Price behavior in different market structures. Profit maximization under different market structures. Role of government in market economies.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Baye, M., & Prince, J. (2022). Managerial economics and business strategy (10th ed.). McGraw Hill.
2. Hirschey, M. (2013). Managerial economics (12th ed.). Cengage Learning.
3. Koutsoyiannis, A. (2008). Modern Microeconomics (2nd ed.). Palgrave, McMillan.
4. Mankiw, N. G. (2024). Principles of Microeconomics (10th ed.). Cengage Learning.
5. Salvator, D., & Rastogi, S.K. (2020). Managerial Economics: Principles and Worldwide Applications (9th ed.). Oxford University Press.
6. Thomas C. R., & Maurice, S.C. (2020). Managerial Economics: Foundations of Business Analysis and Strategy (12th ed.). McGraw Hill.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE
DSE-2(d): MARKETING RESEARCH

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Marketing Research (DSE-2(d))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- This course aims to give the students an in-depth understanding of marketing research and its role in strategic decision-making.
- The course introduces the concepts of marketing research process and research design.
- This course shall provide concepts for measurement, scaling, and sampling design.
- To teach students about data analysis techniques relevant to marketing research.

Learning Outcomes:

Students completing this course will be able to:

- Understand the role of marketing research in strategic decision-making.
- Identify various steps involved in the marketing research process.
- Develop the research objectives and identify the appropriate market research design.
- Manage the Data Collection process.
- Understand different statistical data analysis techniques that are used in marketing research.
- Interpret the data analysis results in the context of the marketing problem under study.

Syllabus of DSE-2(d):

Unit I: Understanding Marketing Research **(5 hours)**

Concept of marketing research and its objectives, Applications of marketing research, Defining the marketing research problem and developing an approach.

Unit II: Research Design Formulation **(8 hours)**

Planning, Research design classification, Potential sources of error, Exploratory and descriptive research, Experimental research.

Unit III: Methods of Data Collection **(12 hours)**

Primary and secondary data collection, Advantages and limitations of primary and secondary data, Measurement and scaling techniques, Questionnaire design process. Sampling: sampling design process, classification of sampling techniques, Non-probability and probability sampling techniques, and sample size determination.

Unit IV: Statistical Techniques for Data Analysis **(20 hours)**

Data processing: Testing of hypothesis, Analysis of variance and covariance, MANOVA, Discriminant Analysis, Factor Analysis, Cluster Analysis, Conjoint Analysis.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Aaker, D. A., Kumara, V., & Day, G. S. (2007). Marketing research. John Wiley & Sons Inc.
2. Green, P. E., Tull, D. S., & Album, G. (1999). Research for marketing decisions: Prentice Hall of India.
3. Hague, P. N., Hague, N., & Morgan, C. A. (2004). Market research in practice: a guide to the basics. Kogan Page Publishers.
4. Heeringa, S. G., West, B. T., & Berglund, P. A. (2017). Applied survey data analysis. Chapman and Hall.
5. Malhotra, N., Hall, J., Shaw, M., & Oppenheim, P. (2006). Marketing research: an applied orientation. Pearson Education.
6. Smith, S. M., & Albaum, G. S. (2005). Fundamentals of marketing research. SAGE Publications Inc.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE
DSE-2(e): QUALITY MANAGEMENT

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Quality Management (DSE-2(e))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- To impart the knowledge of concepts related to quality management.
- To tackle the issues and problems and to develop practical skills for continuous quality improvement.

Learning Outcomes:

Students completing this course will be able to:

- Define quality management concepts, its evolution, and key quality gurus with their contributions.
- Explain statistical concepts like sampling, OC curve and Quality 4.0 for digital transformation.
- Implement SPC tools (CUSUM, EWMA), Six Sigma (DMAIC, DMADV), and defect prevention methods like Poka-yoke and QFD.
- Identify causes of process variation, compare quality improvement techniques, and evaluate benchmarking and Kaizen strategies.
- Assess Six Sigma effectiveness, analyze statistical control tools, and examine the role of Quality 4.0 in modern industries.

Syllabus of DSE-2(e):

Unit I: Evolution and Frameworks of Quality Management (10 hours)
Evolution of quality management, Concepts of product and service quality, Dimensions of quality, Major quality gurus: Deming, Ishikawa, Taguchi; Quality costs, Total quality management, Total quality management excellence model, Quality 4.0: Digital Transformation in Quality.

Unit II: Statistical Process Control and Quality Assurance (12 hours)
Process and product quality, Causes of variations (assignable and unassignable), Statistical process control, Process control charts: variable control charts (X-bar and R, X-bar and S) and attribute control charts (np and p, c and u), CUSUM & EWMA Charts for Early Defect Detection Sampling, Sampling distribution, Acceptance sampling plan: single, double and sequential; Acceptable quality level, Average outgoing quality, Average outgoing quality limit, Operating characteristic curve.

Unit III: Quality Tools and Process Capability **(12 hours)**
Pareto chart, Cause and effect diagram, Check sheet, Histogram, Scatter diagram, Process control charts applications, Graphs: circle graph, bar graph and radar graph. Affinity diagram, Relations diagram, Systematic or tree diagram, Matrix diagram, Matrix data analysis, Arrow diagram, Process capability indices.

Unit IV: Six Sigma, Continuous Improvement and Lean Quality Management **(11 hours)**
Concept of six sigma, Implementation of six sigma: DMAIC, DMADV, Failure mode and effect analysis. Benchmarking for process/service improvement, Concepts of kaizen, Kaizen in practice, Kaizen versus innovation, Lean, 5S, Quality function deployment, Quality control circle, Poka- Yoke.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Besterfield, D. H. (2004). Quality control. India: Pearson Education India.
2. Charantimath, P.M. (2011). Total quality management. India: Pearson Education India.
3. Evans, J. R., & Lindsay, W. M. (2002). The management and control of quality (volume 1). Cincinnati, OH: South-Western.
4. Montgomery, D. C. (2009). Introduction to statistical quality control. New York: John Wiley & Sons.
5. Gupta, S. C., & Kapoor, V. K. (2009). Fundamentals of applied statistics. India: Sultan Chand & Sons.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE
DSE-2(f): SOFT COMPUTING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Soft Computing (DSE-2(f))	4	3	1	0	-	Nil

Learning Objectives:

The learning objectives of this course are as follows:

- Understand the foundational concepts of soft computing, including interval uncertainty, fuzzy logic, neural networks, and genetic algorithms, and their significance in modern computing.
- Analyze and apply soft computing techniques to real-world problems in business, finance, artificial intelligence, and optimization.

Learning Outcomes:

Students completing this course will be able to:

- Understand principles and differences between soft and traditional computing techniques.
- Apply interval analysis and fuzzy logic concepts to create decision-making models for business and finance scenarios.
- Design, train, and implement neural network architectures and genetic algorithms.
- Tackle classification, prediction, and optimization problems using soft computing techniques.

Syllabus of DSE-2(f):

Unit I: Interval Uncertainty **(10 hours)**

Definition and importance of soft computing. Comparison with traditional computing. Definition and representation of intervals. Arithmetic operations on intervals. Properties of interval numbers. Interval uncertainty in business, finance, and optimization applications.

Unit II: Fuzzy Sets and Logic **(11 hours)**

Introduction to fuzzy sets and fuzzy logic. Operations on fuzzy sets. Membership functions. Defuzzification process. Fuzzy relations, rules, and implications. Applications of fuzzy logic.

Unit III: Neural Networks **(12 hours)**

Neural networks: Fundamentals, Single and multiple input neurons, Layers, and Activation functions. Single-layer and multi-layer perceptrons. Types of neural networks: feedforward, and recurrent. Supervised vs. unsupervised learning. Learning algorithm: Gradient descent method. Applications in function approximation, prediction, and classification.

Unit IV: Genetic Algorithms **(12 hours)**

Introduction to Genetic Algorithms. Basic concepts: Encoding methods, Chromosomes, Population, Fitness Function. Operators: Inversion, Selection, Crossover, and Mutation. Applications in optimization, finance, and artificial intelligence.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Rajasekaran, S. & Vijayalakshmi Pai, S. A. (2007). Neural Networks, Fuzzy Logic and Genetic Algorithms: Synthesis, and Applications. Prentice Hall of India.
2. Goldberg D. E. (1989). Genetic Algorithms in Search, Optimization, and Machine Learning. Addison Wesley
3. Moore, R. E., Kearfott, R. B. & Cloud, M. L. (2009). Introduction to Interval Analysis. Society for Industrial and Applied Mathematics, United States.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Skill Enhancement Course – Semester II

SEC - 2: Spreadsheet and Data Visualization

SKILL ENHANCEMENT COURSE
SEC-2: SPREADSHEET MODELING AND DATA VISUALIZATION

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Spreadsheet Modeling and Data Visualization (SEC-2)	**2**	**1**	**0**	**1**	**-**	**Nil**

Learning Objectives:

- To equip students with essential spreadsheet skills for data management, cleaning, visualization, and analysis.
- The course will help students to apply techniques to real-world business analytics and operations research problems.

Learning Outcomes:

Students completing this course will be able to:

- Understand spreadsheet functionalities, including file security, referencing, and formula applications.
- Apply data cleaning techniques to handle missing values, errors, outliers, and text formatting for high-quality datasets.
- Utilize data visualization principles to create meaningful charts, dashboards, and visual comparisons of structured data.
- Perform data analysis using consolidation techniques like what-if analysis, scenario manager, and solver for decision-making.
- Construct and manipulate pivot tables to analyse large datasets, create calculated fields, and generate reports effectively.
- Implement spreadsheet-based analytical solutions in business and operations research applications.

Syllabus of SEC-2:

Unit I: Fundamentals of Spreadsheets and Data Cleaning*

(3 Theory hours + 6 Practical hours)

Basic concepts of Spreadsheets, implementing file level security and protecting data within the worksheet; Understanding absolute, relative and mixed referencing in formulas, referencing cells in other worksheets and workbooks. Data cleaning and processing: Handling Blank Cells & Duplicates, Text Cleaning & Formatting, Finding & Replacing Data: Advance Find & Replace, Handling Errors & Missing Data, Working with Named Ranges, Handling Outliers & Data Validation. Working with inbuilt function categories like mathematical, statistical, text and date functions.

Unit II: Data Visualization: Principles and Techniques*

(4 Theory hours + 8 Practical hours)

Data Visualization: Need, Importance and Usage. Seven Stages of Visualizing Data, Types of Charts. Tabular versus Visual Data Analysis. Dashboards, Visualization of Structured Data: Charts on Univariate, Charts on Visualizing Multiple Measures.

Unit III: **Data Consolidation, Analysis, and Visualization Strategies***

(4 Theory hours + 8 Practical hours)

Data consolidation commands: Performing what-if analysis: Types of what if analysis (manual, data tables, scenario manager), what-if analysis in reverse (goal-seek, solver), Choosing a chart type, understanding data points and data series, editing and formatting chart elements, and creating sparkline graphics.

Unit IV: Data Analysis with Pivot Tables and Applications*

(4 Theory hours + 8 Practical hours)

Constructing a Cross-Tabulation, Analyzing data using pivot tables: Creating, formatting and modifying a pivot table, sorting, filtering and grouping items, creating calculated field and calculated item, creating pivot table charts, producing a report with pivot tables.

*Case Studies and Real-World Applications: Business Analytics and Operations Research Applications.

Essential Readings:

1. Knaflic, C. N. (2015). Storytelling with data: A data visualization guide for business professionals. John Wiley & Sons.
2. Ragsdale, C. T. (2017). Spreadsheet modeling & decision analysis. Thomson south-western.
3. Evans, J. R. (2019). Business analytics: Methods, models, and decisions. Pearson.
4. Evergreen, S. D. (2019). Effective data visualization: The right chart for the right data. SAGE publications.
5. McFedries, P. (2022). Excel Formulas and Functions. Pearson Education.
6. Winston, W. (2021). Microsoft Excel Data Analysis and Business Modeling (Office 2021 and Microsoft 365). Microsoft Press.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Generic Elective - Semester II

GE - 2(a): Queueing Theory

GE - 2(b): Marketing Research

GE - 2(c): Quality Management

GE - 2(d): Soft Computing

GENERIC ELECTIVE
GE-2(a): QUEUEING THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Queueing Theory (GE-2(a))	4	3	1	0	-	Nil

Learning Objectives:

The learning objectives of this course are as follows:

- To impart knowledge of queueing theory and provide the students with a rigorous framework which would enable them to model and analyze queueing systems.
- To provide the students necessary mathematical support and confidence to the students to tackle real life problems.
- To explore both theory and application of fundamental and advanced models in this field.

Learning Outcomes:

Students completing this course will be able to:

- Gain a deep understanding of the theoretical background of queueing systems.
- Understand and compute quantitative metrics of performance for queueing systems.
- Apply and extend queueing models to analyze real world systems.

Syllabus of GE-2(a):

Unit I: Introduction **(10 hours)**

Basic Concepts of Stochastic Process, Markov Chains, Introduction to Queueing Systems, Characteristics of Queueing Systems, Counting Process, Poisson Process (Pure-Birth Process and Pure-Death Process), Expected Measures of System Performance, Queueing Simulation: Data Generation and Book-Keeping.

Unit II: Markovian Queueing Models **(15 hours)**

General Birth-Death Process, Infinite Capacity Queues: Single-Server Queues (M/M/1) and Multi-Server Queues (M/M/c), Finite Capacity Queues: M/M/1/K, M/M/c/K and M/M/c/c (Erlang's Loss System), Queues with Unlimited Service (M/M/∞), Finite-Source Queues, Queues with State-Dependent Service, Queues with Impatience (M/M/1 Balking and M/M/1 Reneging).

Unit III: Advanced Markovian Queueing Models **(15 hours)**

Queues with Bulk Arrival ($M^{[X]}/M/1$), Queues with Bulk Service ($M/M^{[Y]}/1$), Erlangian Queueing Models ($M/E_k/1$ and $E_k/M/1$), Concept of Imbedded Markov Chains, Queues with General Arrivals (G/M/1), Queues with General Service (M/G/1).

Unit IV: Decision Problems in Queueing Systems **(5 hours)**

Design and Control Problems in Queueing Systems, Queueing System with Server Vacation, Queueing System with Removable Server.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Bhat, U. N. (2015). An introduction to Queueing Theory: Modelling and Analysis in Applications (Statistics for Industry and Technology) (2nd Edition). Birkhauser Boston.
2. Cooper, R.B. (1981). Introduction to Queueing Theory (2nd Edition). Elsevier North Holland.
3. Cox, D. R. and Smith, W. L. (1991). Queues. Chapman and Hall/CRC.
4. Gross, Donald, Shortle , John F., Thompson, James M., and Harris, Carl M. (2018). Fundamentals of Queueing Theory (5th Edition), John Wiley and Sons Inc. Pte. Ltd.
5. Kleinrock L. (1975). Queueing Systems, Volume 1: Theory, John Wiley.
6. Medhi, J. (2003). Stochastic Models in Queueing Theory (2nd Edition), Academic Press.
7. Prabhu, N. U. (2012). Foundations of Queueing Theory (International Series in Operations Research & Management Science), Springer (Softcover reprint of the original 1st ed. 1997 edition.)
8. Satty, T. L. (1983). Elements of Queueing Theory with Applications, Dover Publications, NY. (Reprint Edition).

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE
GE-2(b): MARKETING RESEARCH

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Marketing Research (GE-2(b))	4	3	1	0	-	Nil

Learning Objectives:

The learning objectives of this course are as follows:
- This course aims to give the students an in-depth understanding of marketing research and its role in strategic decision-making.
- The course introduces the concepts of marketing research process and research design.
- This course shall provide concepts for measurement, scaling, and sampling design.
- To teach students about data analysis techniques relevant to marketing research.

Learning Outcomes:

Students completing this course will be able to:
- Understand the role of marketing research in strategic decision-making.
- Identify various steps involved in the marketing research process.
- Develop the research objectives and identify the appropriate market research design.
- Manage the Data Collection process.
- Understand different statistical data analysis techniques that are used in marketing research.
- Interpret the data analysis results in the context of the marketing problem under study.

Syllabus of GE-2(b):

Unit I: Understanding Marketing Research **(5 hours)**
Concept of marketing research and its objectives, Applications of marketing research, Defining the marketing research problem and developing an approach.

Unit II: Research Design Formulation **(8 hours)**
Planning, Research design classification, Potential sources of error, Exploratory and descriptive research, Experimental research.

Unit III: Methods of Data Collection **(12 hours)**
Primary and secondary data collection, Advantages and limitations of primary and secondary data, Measurement and scaling techniques, Questionnaire design process. Sampling: sampling design process, classification of sampling techniques, Non-probability and probability sampling techniques, and sample size determination.

Unit IV: Statistical Techniques for Data Analysis **(20 hours)**
Data processing: Testing of hypothesis, Analysis of variance and covariance, MANOVA, Discriminant Analysis, Factor Analysis, Cluster Analysis, Conjoint Analysis.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Aaker, D. A., Kumara, V., & Day, G. S. (2007). Marketing research. John Wiley & Sons Inc.
2. Green, P. E., Tull, D. S., & Album, G. (1999). Research for marketing decisions: Prentice Hall of India.
3. Hague, P. N., Hague, N., & Morgan, C. A. (2004). Market research in practice: a guide to the basics. Kogan Page Publishers.
4. Heeringa, S. G., West, B. T., & Berglund, P. A. (2017). Applied survey data analysis. Chapman and Hall.
5. Malhotra, N., Hall, J., Shaw, M., & Oppenheim, P. (2006). Marketing research: an applied orientation. Pearson Education.
6. Smith, S. M., & Albaum, G. S. (2005). Fundamentals of marketing research. SAGE Publications Inc.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE
GE-2(c): QUALITY MANAGEMENT

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Quality Management (GE-2(c))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The learning objectives of this course are as follows:

- To impart the knowledge of concepts related to quality management.
- To tackle the issues and problems and to develop practical skills for continuous quality improvement.

Learning Outcomes:

Students completing this course will be able to:

- Define quality management concepts, its evolution, and key quality gurus with their contributions.
- Explain statistical concepts like sampling, OC curve and Quality 4.0 for digital transformation.
- Implement SPC tools (CUSUM, EWMA), Six Sigma (DMAIC, DMADV), and defect prevention methods like Poka-yoke and QFD.
- Identify causes of process variation, compare quality improvement techniques, and evaluate benchmarking and Kaizen strategies.
- Assess Six Sigma effectiveness, analyze statistical control tools, and examine the role of Quality 4.0 in modern industries.

Syllabus of GE-2(c):

Unit I: Evolution and Frameworks of Quality Management **(10 hours)**
Evolution of quality management, Concepts of product and service quality, Dimensions of quality, Major quality gurus: Deming, Ishikawa, Taguchi; Quality costs, Total quality management, Total quality management excellence model, Quality 4.0: Digital Transformation in Quality.

Unit II: Statistical Process Control and Quality Assurance **(12 hours)**
Process and product quality, Causes of variations (assignable and unassignable), Statistical process control, Process control charts: variable control charts (X-bar and R, X-bar and S) and attribute control charts (np and p, c and u), CUSUM & EWMA Charts for Early Defect Detection Sampling, Sampling distribution, Acceptance sampling plan: single, double and sequential; Acceptable quality level, Average outgoing quality, Average outgoing quality limit, Operating characteristic curve.

Unit III: Quality Tools and Process Capability **(12 hours)**
Pareto chart, Cause and effect diagram, Check sheet, Histogram, Scatter diagram, Process control charts applications, Graphs: circle graph, bar graph and radar graph. Affinity diagram, Relations diagram, Systematic or tree diagram, Matrix diagram, Matrix data analysis, Arrow diagram, Process capability indices.

Unit IV: Six Sigma, Continuous Improvement and Lean Quality Management **(11 hours)**
Concept of six sigma, Implementation of six sigma: DMAIC, DMADV, Failure mode and effect analysis. Benchmarking for process/service improvement, Concepts of kaizen, Kaizen in practice, Kaizen versus innovation, Lean, 5S, Quality function deployment, Quality control circle, Poka- Yoke.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Besterfield, D. H. (2004). Quality control. India: Pearson Education India.
2. Charantimath, P.M. (2011). Total quality management. India: Pearson Education India.
3. Evans, J. R., & Lindsay, W. M. (2002). The management and control of quality (volume 1). Cincinnati, OH: South-Western.
4. Montgomery, D. C. (2009). Introduction to statistical quality control. New York: John Wiley & Sons.
5. Gupta, S. C., & Kapoor, V. K. (2009). Fundamentals of applied statistics. India: Sultan Chand & Sons.

Suggested Readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE
GE-2(d): SOFT COMPUTING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Soft Computing (GE-2(d))	4	3	1	0	-	Nil

Learning Objectives:

The learning objectives of this course are as follows:

- Understand the foundational concepts of soft computing, including interval uncertainty, fuzzy logic, neural networks, and genetic algorithms, and their significance in modern computing.
- Analyze and apply soft computing techniques to real-world problems in business, finance, artificial intelligence, and optimization.

Learning Outcomes:

Students completing this course will be able to:

- Understand principles and differences between soft and traditional computing techniques.
- Apply interval analysis and fuzzy logic concepts to create decision-making models for business and finance scenarios.
- Design, train, and implement neural network architectures and genetic algorithms.
- Tackle classification, prediction, and optimization problems using soft computing techniques.

Syllabus of DSE-2(f):

Unit I: Interval Uncertainty **(10 hours)**

Definition and importance of soft computing. Comparison with traditional computing. Definition and representation of intervals. Arithmetic operations on intervals. Properties of interval numbers. Interval uncertainty in business, finance, and optimization applications.

Unit II: Fuzzy Sets and Logic **(11 hours)**

Introduction to fuzzy sets and fuzzy logic. Operations on fuzzy sets. Membership functions. Defuzzification process. Fuzzy relations, rules, and implications. Applications of fuzzy logic.

Unit III: **Neural Networks** **(12 hours)**

Neural networks: Fundamentals, Single and multiple input neurons, Layers, and Activation functions. Single-layer and multi-layer perceptrons. Types of neural networks: feedforward, and recurrent. Supervised vs. unsupervised learning. Learning algorithm: Gradient descent method. Applications in function approximation, prediction, and classification.

Unit IV: Genetic Algorithms **(12 hours)**

Introduction to Genetic Algorithms. Basic concepts: Encoding methods, Chromosomes, Population, Fitness Function. Operators: Inversion, Selection, Crossover, and Mutation. Applications in optimization, finance, and artificial intelligence.

Tutorial component (if any) - Yes **(15 hours)**

Practical component (if any) - Nil

Essential Readings:

1. Rajasekaran, S. & Vijayalakshmi Pai, S. A. (2007). Neural Networks, Fuzzy Logic and Genetic Algorithms: Synthesis, and Applications. Prentice Hall of India.
2. Goldberg D. E. (1989). Genetic Algorithms in Search, Optimization, and Machine Learning. Addison Wesley
3. Moore, R. E., Kearfott, R. B. & Cloud, M. L. (2009). Introduction to Interval Analysis. Society for Industrial and Applied Mathematics, United States.

Suggested Readings: Nil

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