UNIVERSITY OF DELHI

CNC-II/093/1/EC-1275/25/15
Dated: 31.07.2025

NOTIFICATION

Sub: Amendment to Ordinance V

(ECR 07-20/ dated 23.05.2025)

Following addition be made to Annexure-II-A to the Ordinance V (2-A) of the Ordinances of the University;

Add the following:

The syllabi of Semester VII and Semester VIII of Department of Operational Research under Faculty of Mathematical Sciences based on Undergraduate Curriculum Framework 2022 are notified herewith for the information of all concerned as per ***Annexure-1.***

REGISTRAR

Annexure-1

OPERATIONAL RESEARCH

COURSES OFFERED BY DEPARTMENT OF OPERATIONAL RESEARCH

Category I

Operational Research Courses for Undergraduate Programme of Study with Operational Research as a Single Core Discipline

(B.Sc. Honours in Operational Research Course in four years)

STRUCTURE OF SEVENTH SEMESTER

DISCIPLINE SPECIFIC CORE COURSE – 19: DECISION ANALYSIS AND GAME 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 Analysis and Game Theory (DSC - 19)	4	3	1	0		Nil

Learning Objectives:

The Learning Objectives of this course are as follows:

- To teach how optimal choice can be made amongst alternative courses of actions (decisions) with uncertain consequences using non-probabilistic and utility theory approaches
- To analyze decision support systems using decision trees
- This course also explores matrix game theory and its application to business and economics.

Learning Outcomes:

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

- Analyze problems when the decision maker has no knowledge about various states of nature; not even sufficient to permit the assignment of probabilities to them.
- Obtain optimal decisions using graphical approach-decision trees.
- Understand the basic concepts of game theory and its relevance to business and economics.
- Analyse and develop strategies for matrix games involving 2-persons.

Syllabus of DSC-19:

Unit I: Basics of Decision Analysis (8 hours)

Prescriptive decision analysis; history of decision analysis; Basic elements of decision analysis; Modelling of Decision Problems; Non-probabilistic criteria for decision making under uncertainty: Preference Orderings, The Maximin Rule, The Minimax Regret Rule, Hurwicz Principle, Laplace Principle of equi-likelihood.

Unit II: Decision Analysis under Risk-Probabilistic Approach (15 hours)

Decision Analysis without Sampling, EMV criterion, EOL criterion, cost of uncertainty: EVPL; Bayes Theorem, Decision Analysis with Sampling, Value of Information: EVSI, ENGS; Decision Trees.

Unit III: 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. Cooperative and non-cooperative games: Examples involving two-persons and n-persons.

Unit IV: **Matrix Games (12 hours)**

Two-person zero-sum games: Saddle points, Mixed strategies, Fundamental theorem, Solution of matrix games of size **2 x 2, 2 x n, m x 2 and m x n**. Examples of matrix games in business applications. Introduction to non-zero-sum game.

Suggestive Tutorial Activities: (15 hours)

1. Solving problems based on decsion-making under strict uncertainty, without sampling, and with sampling.
2. Constructing and analyzing decision trees.
3. Practice exercises on game-theoretic models: dominance, saddle-point, and mixed strategies.
4. Application-based discussions and small group case exercises.
5. Software Exercises: Modeling and analyzing decision models and decision trees in Excel; Simulating game matrices and solving for strategies using Python / R.

Practical component (if any) - Nil

Essential Readings:

1. Taha, H.A. (2007) Operations Research-An Introduction, 8th Edition, Prentice Hall.
2. Jones, J. M (1977). Introduction to decision theory, irwin series in quantitative analysis for business (1st ed.). New York: Irwin (Richard D.) Inc.
3. Mastumoto, A., & Szidarovszky, F. (2016). *Game theory and its applications*. Springer.
4. 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.

Category II

Operational Research Courses for Undergraduate Programme of Study with Operational Research as one of the Core Disciplines

(B.A. Programme with Operational Research as Major Discipline)

DISCIPLINE SPECIFIC CORE COURSE – 13: DECISION ANALYSIS AND GAME 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 Analysis and Game Theory (DSC - 13)	4	3	1	0		Nil

Learning Objectives:

The Learning Objectives of this course are as follows:

- To teach how optimal choice can be made amongst alternative courses of actions (decisions) with uncertain consequences using non-probabilistic and utility theory approaches
- To analyze decision support systems using decision trees
- This course also explores matrix game theory and its application to business and economics.

Learning Outcomes:

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

- Analyze problems when the decision maker has no knowledge about various states of nature; not even sufficient to permit the assignment of probabilities to them.
- Obtain optimal decisions using graphical approach-decision trees.
- Understand the basic concepts of game theory and its relevance to business and economics.
- Analyse and develop strategies for matrix games involving 2-persons.

Syllabus of DSC-13:

Unit I: Basics of Decision Analysis **(8 hours)**

Prescriptive decision analysis; history of decision analysis; Basic elements of decision analysis; Modelling of Decision Problems; Non-probabilistic criteria for decision making under uncertainty: Preference Orderings, The Maximin Rule, The Minimax Regret Rule, Hurwicz Principle, Laplace Principle of equi-likelihood.

Unit II: Decision Analysis under Risk-Probabilistic Approach (15 hours)
Decision Analysis without Sampling, EMV criterion, EOL criterion, cost of uncertainty: EVPL; Bayes Theorem, Decision Analysis with Sampling, Value of Information: EVSI, ENGS; Decision Trees.

Unit III: 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. Cooperative and non-cooperative games: Examples involving two-persons and n-persons.

Unit IV: **Matrix Games (12 hours)**
Two-person zero-sum games: Saddle points, Mixed strategies, Fundamental theorem, Solution of matrix games of size **2 x 2, 2 x n, m x 2 and m x n**. Examples of matrix games in business applications. Introduction to non-zero-sum game.

Suggestive Tutorial Activities: (15 hours)

1. Solving problems based on decision-making under strict uncertainty, without sampling, and with sampling.
2. Constructing and analyzing decision trees.
3. Practice exercises on game-theoretic models: dominance, saddle-point, and mixed strategies.
4. Application-based discussions and small group case exercises.
5. Software Exercises: Modeling and analyzing decision models and decision trees in Excel; Simulating game matrices and solving for strategies using Python / R.

Practical component (if any) - Nil

Essential Readings:

1. Taha, H.A. (2007) Operations Research-An Introduction, 8th Edition, Prentice Hall.
2. Jones, J. M (1977). Introduction to decision theory, irwin series in quantitative analysis for business (1st ed.). New York: Irwin (Richard D.) Inc.
3. Mastumoto, A., & Szidarovszky, F. (2016). *Game theory and its applications*. Springer.
4. 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.

Category III

Operational Research Courses for Undergraduate Programme of Study with Operational Research as one of the Core Disciplines

(B.A. Programme with Operational Research as non-Major or Minor Discipline)

DISCIPLINE SPECIFIC CORE COURSE – 7: DECISION ANALYSIS AND GAME 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 Analysis and Game Theory (DSC - 7)	4	3	1	0		Nil

Learning Objectives:

The Learning Objectives of this course are as follows:

- To teach how optimal choice can be made amongst alternative courses of actions (decisions) with uncertain consequences using non-probabilistic and utility theory approaches
- To analyze decision support systems using decision trees
- This course also explores matrix game theory and its application to business and economics.

Learning Outcomes:

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

- Analyze problems when the decision maker has no knowledge about various states of nature; not even sufficient to permit the assignment of probabilities to them.
- Obtain optimal decisions using graphical approach-decision trees.
- Understand the basic concepts of game theory and its relevance to business and economics.
- Analyse and develop strategies for matrix games involving 2-persons.

Syllabus of DSC-7:

Unit I: Basics of Decision Analysis **(8 hours)**

Prescriptive decision analysis; history of decision analysis; Basic elements of decision analysis; Modelling of Decision Problems; Non-probabilistic criteria for decision making under uncertainty: Preference Orderings, The Maximin Rule, The Minimax Regret Rule, Hurwicz Principle, Laplace Principle of equi-likelihood.

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

Decision Analysis without Sampling, EMV criterion, EOL criterion, cost of uncertainty: EVPL; Bayes Theorem, Decision Analysis with Sampling, Value of Information: EVSI, ENGS; Decision Trees.

Unit III: 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. Cooperative and non-cooperative games: Examples involving two-persons and n-persons.

Unit IV: **Matrix Games** **(12 hours)**

Two-person zero-sum games: Saddle points, Mixed strategies, Fundamental theorem, Solution of matrix games of size **2 x 2, 2 x n, m x 2 and m x n**. Examples of matrix games in business applications. Introduction to non-zero-sum game.

Suggestive Tutorial Activities: **(15 hours)**

1. Solving problems based on decision-making under strict uncertainty, without sampling, and with sampling.
2. Constructing and analyzing decision trees.
3. Practice exercises on game-theoretic models: dominance, saddle-point, and mixed strategies.
4. Application-based discussions and small group case exercises.
5. Software Exercises: Modeling and analyzing decision models and decision trees in Excel; Simulating game matrices and solving for strategies using Python / R.

Practical component (if any) - Nil

Essential Readings:

1. Taha, H.A. (2007) Operations Research-An Introduction, 8th Edition, Prentice Hall.
2. Jones, J. M (1977). Introduction to decision theory, irwin series in quantitative analysis for business (1st ed.). New York: Irwin (Richard D.) Inc.
3. Mastumoto, A., & Szidarovszky, F. (2016). *Game theory and its applications*. Springer.
4. 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.

Category IV

B.Sc. Physical Sciences/ Mathematical Sciences with Operational Research as one of the three Core Disciplines

DISCIPLINE SPECIFIC CORE COURSE – 7: DECISION ANALYSIS AND GAME 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 Analysis and Game Theory (DSC - 7)	4	3	1	0		Nil

Learning Objectives:

The Learning Objectives of this course are as follows:

- To teach how optimal choice can be made amongst alternative courses of actions (decisions) with uncertain consequences using non-probabilistic and utility theory approaches
- To analyze decision support systems using decision trees
- This course also explores matrix game theory and its application to business and economics.

Learning Outcomes:

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

- Analyze problems when the decision maker has no knowledge about various states of nature; not even sufficient to permit the assignment of probabilities to them.
- Obtain optimal decisions using graphical approach-decision trees.
- Understand the basic concepts of game theory and its relevance to business and economics.
- Analyse and develop strategies for matrix games involving 2-persons.

Syllabus of DSC-7:

Unit I: Basics of Decision Analysis **(8 hours)**

Prescriptive decision analysis; history of decision analysis; Basic elements of decision analysis; Modelling of Decision Problems; Non-probabilistic criteria for decision making under uncertainty: Preference Orderings, The Maximin Rule, The Minimax Regret Rule, Hurwicz Principle, Laplace Principle of equi-likelihood.

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

Decision Analysis without Sampling, EMV criterion, EOL criterion, cost of uncertainty: EVPL; Bayes Theorem, Decision Analysis with Sampling, Value of Information: EVSI, ENGS; Decision Trees.

Unit III: 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. Cooperative and non-cooperative games: Examples involving two-persons and n-persons.

Unit IV: **Matrix Games** **(12 hours)**

Two-person zero-sum games: Saddle points, Mixed strategies, Fundamental theorem, Solution of matrix games of size **2 x 2, 2 x n, m x 2 and m x n**. Examples of matrix games in business applications. Introduction to non-zero-sum game.

Suggestive Tutorial Activities: **(15 hours)**

1. Solving problems based on decision-making under strict uncertainty, without sampling, and with sampling.
2. Constructing and analyzing decision trees.
3. Practice exercises on game-theoretic models: dominance, saddle-point, and mixed strategies.
4. Application-based discussions and small group case exercises.
5. Software Exercises: Modeling and analyzing decision models and decision trees in Excel; Simulating game matrices and solving for strategies using Python / R.

Practical component (if any) - Nil

Essential Readings:

1. Taha, H.A. (2007) Operations Research-An Introduction, 8th Edition, Prentice Hall.
2. Jones, J. M (1977). Introduction to decision theory, irwin series in quantitative analysis for business (1st ed.). New York: Irwin (Richard D.) Inc.
3. Mastumoto, A., & Szidarovszky, F. (2016). *Game theory and its applications*. Springer.
4. 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.

CATEGORY-V

B.Sc. (H) OR/BA(P)with OR Major & Minor/B.Sc. (Physical Sciences/Mathematical Sciences) with OR as one of the three core Disciplines
COMMON POOL OF DISCIPLINE SPECIFIC ELECTIVES (DSE) COURSES offered by the parent Department, i.e., Department of Operational Research as choice based electives

DISCIPLINE SPECIFIC ELECTIVE
(DSE-5(a): INTRODUCTION TO 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		
Introduction to Marketing Research (DSE-5(a))	4	3	1	0	-	Nil

Learning Objectives:

The Learning Objectives of this course are as follows:

- To introduce the students to the fundamentals of marketing research and its role in decision making.
- To introduce the concepts of marketing research process, research design, measurement and scaling.
- To develop a broad understanding of the sampling process.
- To explain the various data analysis techniques relevant to marketing research.
- To understand about the diffusion dynamics of products.

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.
- Understand the mathematical modeling for an innovation diffusion process.

Syllabus of DSE-5(a):

Unit I: Introduction to Marketing Research (7 hours)

Introduction to Marketing Research and its objectives, Marketing Research Process, Formulation of Marketing Research problem, Different Types of Marketing Research Problems, Developing an approach to the research problem; Marketing Research Design: Exploratory, Descriptive and Causal Research Design.

Unit II: Marketing Data Collection and Processing (15 hours)
Primary and Secondary Marketing Data and their collection methods, Measurement & Scaling, Questionnaire Design, Sampling Techniques and Determination of Sample Size. Data processing, Hypothesis Testing, Analysis of Variance, Correlation and Regression, Statistical Techniques for consumer behaviour and market segmentation.

Unit III: Marketing Research for New Product Planning (8 hours)
Introduction of a new product: Utility measures for product search. Break-even analysis for product Evaluation, PERT, and CPM in product development.

Unit IV: Diffusion of Innovation (15 hours)
Diffusion of Innovation and its elements, Characteristics of Innovation, Rate of Adoption, Rogers' theory of Adopter categories, Mathematical models for Innovation diffusion under Internal Influence, External Influence and mixed Influence.

Suggestive Tutorial Activities: (15 hours)

1. Designing market surveys and sampling plans.
2. Tabulation and statistical analysis of collected data.
3. Application of hypothesis testing and regression to marketing problems.
4. Presentation of mini-projects based on product/consumer research.

Practical component (if any) - Nil

Essential Readings:

1. Malhotra, N., Nunan, D., & Birks, D. (2017). Marketing research: An applied approach. Pearson.
2. Kumar, V., Leone, R. P., Aaker, D. A., & Day, G. S. (2018). Marketing research. John Wiley & Sons.
3. Everett R. (2003) Diffusions of Innovations, Simon & Schuster Publishers; 5th edition
4. Lilien, Gary.L., Kotler P.& Moorthy K. Sridhar (1998) Marketing Models, Prentice Hall India Learning Private Limited.

Suggestive Readings:

1. Anand, A., Aggrawal, D., & Agarwal, M. (2019). Market assessment with OR applications. CRC press.
2. Hague, P. N., Hague, N., & Morgan, C. A. (2004). Market research in practice: a guide to the basics. Kogan Page Publishers.

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

DISCIPLINE SPECIFIC ELECTIVE
(DSE-5(b): ADVANCED INVENTORY 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		
Advanced Inventory Management (DSE-5(b))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The Learning Objectives of this course are as follows:

- To enrich students with advanced inventory control techniques and their implementation in realistic scenarios.
- It will provide an in-depth study of classical models for inventory management and their extensions, modelling approaches to multi-echelon inventory systems.

Learning Outcomes:

Students completing this course will be able to:

- Understand classical inventory models and their extensions.
- Make use of a set of quantitative tools for analysing the costs and optimal solutions for inventory policies in different environments.
- Comprehend multi-echelon inventory systems that have been proposed in the literature
- Evaluate the significance of inventory control in supply chains.
- Understand the fundamental concepts of Material Requirement Planning (MRP) and Material Management.

Syllabus of DSE- 5(b):

Unit I: **Overview of the EOQ model and its extensions** **(13 hours)**
Types of inventory models. Inventory model for discrete demand with and without shortages. Inventory models with time-varying demand. Lot sizing models for perishable items. Multiple items inventory models with constraints.

Unit II: Advance Inventory models **(13 hours)**
Introduction to safety stock and Service Level. Models for uncertain lead time demand and uncertain lead time. Periodic and Continuous Review models - (R, Q) and (s, S) policy. Multi-echelon inventory optimization and planning. Warehousing Problems in Inventory Management.

Unit III: Production Planning and Scheduling: **(6 hours)**
Aggregate planning, Master Production Schedule. Introduction to – Just in Time (JIT), Kanban system, and Vendor-Managed Inventory.

Unit IV: Inventory control in Supply-Chains **(13 hours)**

Material Requirement Planning (MRP), Approaches and benefits of MRP. Introduction to MRP I and MRP II. Inputs to an MRP system. Dependent Demand, Bill of Material, Determining Net Requirement, Time Phased Order Point.

Suggestive Tutorial Activities: **(15 hours)**

1. EOQ models with practical variations (backorders, quantity discounts).
2. Solving probabilistic inventory and safety stock problems.
3. Multi-level inventory case applications and simulations.
4. Review of ERP/MRP and real-world examples.
5. Software Exercises: EOQ modeling in Excel; stochastic simulation in Python; Analysis of inventory systems using R.

Practical component (if any) – Nil

Essential Readings:

1. Arrow, K. J., Karlin, S., & Scarf, H. E. (1958). *Studies in the mathematical theory of inventory and production*. Stanford University Press.
2. Axsäter, S. (2015). *Inventory control*. Springer.
3. Hadley, G., & Whitin, T. M. (1963). *Analysis of inventory systems*. Prentice-Hall.
4. Muckstadt, J.A., & Sapra, A. (2010). Principles *of Inventory Management: When You Are Down to Four, Order More*. Springer-Verlag.
5. Naddor, E. (1966). *Inventory Systems*. Wiley.
6. Ploss, G. W. (1985). *Production and Inventory Control-Principle and Techniques.*2nd Edition. Prentice Hall.
7. Porteus, E. L. (2002). *Foundations of stochastic inventory theory*. Stanford University Press.
8. Schwarz, L. B. (1981). *Multi-level production/inventory control systems: theory and practice*. North Holland.
9. Silver, E. A., Pyke, D. F., & Thomas, D. J. (2016). *Inventory and production management in supply chains*. CRC press.
10. Sherbrooke, C. C. (2004). Optimal inventory modeling of systems: multi-echelon techniques. 2nd Edition. Springer.
11. Zipkin, H. P. (2000). *Foundations of Inventory Systems*. McGraw-Hill.

Suggestive 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-5(c): PORTFOLIO 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		
Portfolio Management (DSE-5(c))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The Learning Objectives of this course are as follows:

- Understand the fundamentals of investment, portfolio management, risk-return concepts, asset types, and financial markets, and apply portfolio construction and diversification methods.
- Analyse the portfolio optimization process using techniques like Markowitz theory, performance evaluation, and the principles of capital market theory to make informed investment decisions.

Learning Outcomes:

Students completing this course will be able to:

- Comprehend the core concepts of investment, risk-return relationships, and portfolio construction.
- Analyse different types of assets, risk factors, and methods to compute and forecast returns and risks.
- Apply portfolio management strategies, including diversification, short selling, and efficient frontier analysis.
- Understand the functioning of financial markets, types of orders, and investment alternatives like equities, bonds, and global options.
- Evaluate portfolio performance using metrics such as Sharpe ratio, Jensen ratio, and CAPM.
- Develop the ability to optimize portfolios using models like Markowitz theory, CML, and SML for improved investment decision-making.

Syllabus of DSE-5(c):

Unit I: Investment Fundamentals and Portfolio Management Process (11 hours)

Investment and its importance, return and risk, sources of risk, types of return and risk, computation of risk and return from historical data, computation of expected rate of return and risk, determinants of required rate of return, factors influencing required rate of return, time value of money, compounding and discounting, present and future value of equity, investor's strategies and goals across life cycle, construction of policy statement, portfolio management process.

Unit II: Investment Alternatives and Financial Markets (14 hours)

Investment alternatives: Money market instruments, fixed income investments, equity investments, special equity instruments (warrants and options), future contracts, low liquidity investments, global investment choices. Market characteristics, function and classification of financial markets, primary capital market, secondary bond and equity markets, third market, regional stock exchanges. Types of orders: limit order, market order, special orders, margin transactions, short selling. Uses of security market indexes, factors for constructing market indexes, methods of calculating market indexes, different types of market indexes.

Unit III: Portfolio Theory and Optimization (11 hours)

Markowitz portfolio theory assumptions, calculation of mean rate of return and risk for a portfolio of assets, measures of covariance and correlation between asset returns, risk-return relationship for portfolios with different returns, standard deviation, and correlation, efficient frontier, selection of optimal portfolio through investor's utility and efficient frontier, portfolio optimization models, two fund theorem.

Unit IV: Capital Market Theory and Portfolio Performance Evaluation (9 hours)

Assumptions of capital market theory, development of capital market line (CML), benefits of portfolio diversification, investing with CML, capital asset pricing model (CAPM), security market line (SML), one fund theorem, portfolio performance evaluation.

Suggestive Tutorial Activities: (15 hours)

1. Practical computation of risk and expected return using historical investment data.
2. Hands-on exercises on calculating and comparing different types of market indexes.
3. Exercises on selecting optimal portfolios using utility curves, efficient frontier, and optimization models.
4. Application of CAPM, SML, and the one-fund theorem in evaluating portfolio performance.
5. Use of software tools for portfolio analysis.

Practical component (if any) – Nil

Essential Readings:

1. Grinold, R. C., & Kahn, R. N. (1999). Active portfolio management-a quantitative approach for producing superior returns and controlling risk. New York: McGraw Hill.
2. Luenberger, D. G. (2010). Investment science. New York: Oxford University Press Inc. (Indian Print).
3. Markowitz, H. M. (2000). Mean-variance analysis in portfolio choice and capital markets. New Jersey: Wiley.
4. Marrison, C. (2002). The fundamentals of risk measurement. New York: McGraw Hill.
5. Reilly, F. K., & Brown, K. C. (2009). Investment analysis and portfolio management (10th ed.). South-Western: Cengage Learning.
6. Roman, S. (2004). Introduction to the mathematics of finance: from risk management to options pricing. Berlin: Springer.

Suggested Readings:

1. Gupta, P., Mehlawat, M. K., Inuiguchi, M., & Chandra, S. (2014). Fuzzy portfolio optimization: advances in hybrid multi-criteria methodologies. Berlin: Springer.
2. Sharpe, W. F. (1999). Portfolio theory and capital markets. New York: McGraw Hill.

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

DISCIPLINE SPECIFIC ELECTIVE
(DSE-5(d): STATISTICAL 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		
Statistical Computing (DSE-5(d)	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

- Learn computationally intensive methods of use to data analysts.
- To teach simulating random variables from probability distributions and generating random processes: Poisson process and renewal processes.
- To teach Monte Carlo integration and variance reduction methods.
- To teach bootstrap and jackknife.
- To teach MCMC methods.
- To teach density estimation.

Learning Outcomes:

Students completing this course will be able to:

- Learn how samples can be drawn from Binomial, Poisson, normal, and exponential populations and learn how to generate random processes: Poisson processes and renewal processes.
- Learn Monte Carlo methods of use in estimation and inference.
- Learn Resampling Methods: Bootstrapping and Jackknife.
- Learn MCMC that can be used to generate a random sample from the distribution that approximates the target density.
- Learn methods for estimating probability density function.

Syllabus of DSE-5(d):

Unit I: Methods of Generating Random Variables **(9 hours)**
Introduction; Inverse Transformation Methods: Discrete Case and Continuous Case; Acceptance-Rejection Methods; Transformation Methods; Generating Random Processes: Poisson Processes and Renewal Processes.

Unit II: **Monte Carlo Integration** **(8 hours)**
Simple Monte Carlo Estimator, Variance and Efficiency; Variance Reduction; Importance Sampling, Monte Carlo Estimation and Standard Error; Estimation of Mean Squares Error; Estimating a Confidence Level.

Unit III: Bootstrap and Jackknife Methods **(14 hours)**
Bootstrap Estimation of Standard Error, Bootstrap Estimation of Bias, Jackknife; Basic Bootstrap Confidence Interval; Standard Normal Bootstrap Confidence Interval.

Unit IV: Markov Chain Monte Carlo Methods **(14 hours)**

A review of Bayes Theorem and Markov Chains; Markov Chain Monte Carlo Integration; Metropolis-Hastings Algorithm; Gibbs Sampler.

Suggestive Tutorial Activities: **(15 hours)**

1. Simulation of distributions (Binomial, Normal, and Exponential) and random processes (Homogeneous Poisson Process and Non-Homogeneous Poisson Process).
2. Bootstrapping and jackknife techniques for statistical inference.
3. Monte Carlo-based estimation and problem-solving.
4. Practical exercises on real-life datasets.
5. Software Exercises: simulation and Resampling using R /Python.

Practical component (if any) – Nil

Essential Readings:

1. B. Efron and R. Tibshirani. An Introduction to the Bootstrap. Chapman & Hall/CRC, Boca Raton, FL, 1993.
2. B. D. Ripley. Stochastic Simulation. Cambridge University Press, 1987.
3. C. P. Robert and G. Casella. Monte Carlo Statistical Methods. Springer, New York, Second edition, 2004.
4. D. Kundu and A. Basu, editors. Statistical Computing: Existing Methods and Recent Developments. Alpha Science International Ltd., Harrow, U.K., 2004.
5. J. Shao and D. Tu. The Jackknife and Bootstrap. Springer, New York, 1995.
6. S. M. Ross. Simulation. Academic Press, San Diego, fifth edition, 2013.

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-5(e): QUEUEING NETWORKS)

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 Networks (DSE-5(e))	4	3	1	0	-	Nil

Learning Objectives:

The Learning Objectives of this course are as follows:

- To acquaint students with the theory of queueing networks which are powerful and versatile tool for the performance evaluation and prediction of resource sharing systems such as computer, communication, traffic, manufacturing systems.
- To introduce techniques to solve various types of queuing networks analytically and numerically.

Learning Outcomes:

Students completing this course will be able to:

- Learn about the networks of queues and its classification.
- Understand product-form networks.
- Learn various algorithms used to solve different types of networks, and to evaluate their measures of performance.
- Learn various application areas of queueing networks through case studies.

Syllabus of DSE – 5(e):

Unit I: Introduction to queueing networks (9 hours)
Classification and basic concepts, Single class networks, Performance measures of queueing networks, Product-form networks.

Unit II: Open queueing networks (14 hours)
Definition, Series queues (Tandem queues), Queue output (Burke's output theorem), Single class open networks: Traffic equations, Stability conditions, Open Jackson network, Jackson's theorem for solving open networks, Derivation of performance measures.

Unit III: Closed queueing networks (14 hours)
Definition, Cyclic networks, Gordon-Newell networks, Gordon-Newell theorem for solving closed networks, Derivation of performance measures, Mean-Value Analysis (MVA) algorithm for closed networks.

Unit IV: Applications of queueing networks (8 hours)
Computer systems and communication systems, Service industry, Supply chain management.

Suggestive Tutorial Activities: (15 hours)

1. Practice problems on basic and multi-server queueing models.
2. Exercise on tandem queueing networks and Jackson networks using Jackson's theorem.
3. Exercise on closed queueing networks using Gordon-Newell theorem and MVA.
4. Real-life applications of queuing theory in service sectors.
5. Case-based exercises and performance analysis.

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. Bolch, Gunter, Meer, Hermann de, Trivedi, Kishor Shridharbhai, and Greiner, Stefan. (2006). Queueing Networks and Markov Chains: Modeling and Performance Evaluation with Computer Science Applications, John Wiley & Sons, Inc., Hoboken, New Jersey.
3. Chen, H. and Yao, David D. (2001). Fundamentals of Queueing Networks- Performance, Asymptotics and Optimization, Springer-Verlag.
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. Kelly, Frank, and Yudovina, Elena. (2014). Stochastic Networks, Cambridge University Press.
6. Kobayashi H., and Mark, Brian L. (2008). System Modelling and Analysis- Foundations of System Performance Evaluation, Prentice-Hall.
7. Robertazzi, T. G. (2000). Computer Networks and Systems - Queueing Theory and Performance Evaluation (3rd Edition), Springer.

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-5(f): RESEARCH METHODOLOGY)

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		
Research Methodology (DSE-5(f))	**4**	**3**	**0**	**1**	**-**	**Nil**

Learning Objectives:

- To give students an understanding of quantitative and qualitative research's basic techniques and tools.
- To provide exposure to the students about the nature and extent of research orientation, which they are expected to possess for higher studies, research, and the job market.

Learning Outcomes:

Upon successful completion of this course, the student will be able to:

- Identity and analyse research problems.
- Understand and apply the types of research designs and research tools.
- Do data collection and formulate research questionnaires and conduct surveys.
- Present research reports.

Syllabus of DSE-5(f):

Unit I: Research: Role and Scope (6 hours)
Nature and scope of Research – Role of Research in decision making. Applications of research in various disciplines. The Research Process – Steps in the research process; the research proposal.

Unit II: Research Design and Documentation (12 hours)
Research Design: Exploratory, Descriptive, Causal. Secondary Data Research: Advantages & Disadvantages of Secondary Data, Criteria for evaluating secondary sources, secondary sources of data in Indian Context, Syndicated Research (in India).

Unit III: Data and Scaling (14 hours)
Primary Data Collection: Survey vs. Observations. Qualitative Research Tools: Depth Interviews focus groups and projective techniques; Measurement & Scaling: Primary scales of Measurement- Nominal, Ordinal, Interval& Ratio. Scaling techniques- paired comparison, rank order scale, constant sum scale, semantic differential scale, itemized ratings, scale, Likert Scale; Questionnaire- form & design**.**

Unit IV: Sampling (13 hours)
Sampling: Sampling techniques, Data Analysis: Chi-square test, non-parametric test: Mann Whitney U test, Wilcoxon Signed-Rank test for paired samples, One-Way ANOVA Analysis, Factor Analysis and Discriminant Analysis. Conjoint Analysis, Report writing.

Suggestive Tutorial Activities: Nil

Practical component (if any) – (30 hours)

Use Microsoft Excel/SPSS for practical labs for Research Methodology.

List of Practical:

1. Chi-square Test
2. Mann Whitney U test.
3. Wilcoxon Signed-Rank Test.
4. One Way ANOVA
5. Factor Analysis (PCA)
6. Discriminant Analysis (LDA)

Essential Readings:

1. Cooper, D. R., & Schindler, P. S. (2003). Business research methods, McGraw- Hill Education, India
2. Malhotra, N. K. (2019). Marketing Research: An Applied Orientation (7th Ed.). Pearson India.
3. Chawla, D., & Sondhi, N. (2016). Research Methodology: Concepts and Cases, Vikas Publishing House, India

Suggestive Readings:

1. Winston, W. L. (2014). *Marketing analytics: Data-driven techniques with Microsoft Excel*. John Wiley & Sons.

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

CATEGORY-VI

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES OFFERED BY THE DEPARTMENT

GENERIC ELECTIVE
(GE-7(a): QUANTITATIVE FINANCE)

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		
Quantitative Finance (GE-7(a))	4	3	1	0	-	Nil

Learning Objectives:

The Learning Objectives of this course are as follows:

- To make students understand the basics of quantitative finance.
- To familiarize them with the principles, practices, techniques and applications of quantitative finance, so as to enable them to deal with various business decisions in an efficient manner.

Learning Outcomes:

Students completing this course will be able to:

- Relate financial knowledge to varied decisions in a business environment.
- Gain an understanding of financial assets.
- Utilize the concepts, techniques and methods of finance for quantitative analysis.
- Convey financial information and prepare financial management solutions.

Syllabus of GE-7(a):

Unit I: Introduction to Finance Functions and Time Value of Money (14 hours)

Purpose and objectives of Quantitative finance, financial markets, Functions of finance: Investment, Financing and Dividend decisions, roles and responsibilities of a finance manager. Time value of money: Present value and Future value; Ordinary Annuity, Annuity Due, and Perpetuity; Valuation of securities: Bonds and their valuation, Bond Yields, Common and preferred stock and their valuation.

Unit II: Risk-Return trade-off (9 hours)

Introduction to Risk and Return: Concept and significance, application of standard deviation and coefficient of variation, systematic and unsystematic risks, risk and return in a portfolio context, Capital Asset Pricing Model (CAPM), alternatives to CAPM.

Unit III: Financial statement analysis (12 hours)
Financial statements: Balance sheet, Income statement, Cash flows statement. Analysis of financial statements: Ratio analysis, Du Pont equations.

Unit IV: Capital Budgeting and Working Capital Management (10 hours)
The long term investment decision: Capital budgeting, Estimation of cash flows. Capital budgeting methods: Discounted and non-discounted cash flow-based techniques. Interpretation and significance of working capital, permanent and temporary working capital, determinants of working capital, Goal Programming model of working capital management, Cash management: motives and objectives; Baumol's model of cash management.

Suggestive Tutorial Activities: (15 hours)

1. Time value of money and annuity-related calculations.
2. Risk-return evaluation of portfolios.
3. Analysis of financial statements using ratio analysis.
4. Exercises in capital budgeting and investment appraisal.
5. Software Exercises: NPV and IRR modeling, Stock return analysis.

Practical component (if any) – Nil

Essential Readings:

1. Gitman, L. J., Juchau, R., & Flanagan, J. (2015). *Principles of managerial finance*. Pearson Higher Education AU.
2. Koller, T., Dobbs, R., & Huyett, B. (2010). *Value: The four cornerstones of corporate finance*. John Wiley & Sons.
3. Levy, H., & Sarnat, M. (1988). *Principles of financial management*. Prentice Hall.
4. Ross, S. A., Westerfield, R., & Jaffe, J. F. (1999). *Corporate finance*. Irwin/McGraw- Hill.
5. Van Horne, J. C., & Wachowicz, J. M. (2008). *Fundamentals of financial management* (13th ed.). Harlow: Prentice Hall Inc.

Suggestive Readings:

1. Blyth, S. (2013). *An introduction to quantitative finance*. Oxford University Press.
2. Wilmott, P. (2013). *Paul Wilmott on quantitative finance*. John Wiley & Sons.

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

GENERIC ELECTIVE
(GE-7 (b)): LOGISTICS AND SUPPLY CHAIN 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		
Logistics and Supply Chain Management (GE-7(b))	4	3	1	0	-	Nil

Learning Objectives:

- To impart the knowledge of concepts and approaches for supply chain management.
- To tackle the issues and problems related to the management of demand and supply of goods and services.
- To develop skills which helps in understanding how the theories relate to practice.

Learning Outcomes:

Students completing this course will be able to:

- Explain the theoretical terminologies related to supply chain management such as logistics, value chain, supply chain and concepts like evolution, integration and importance of supply chain, various elements of supply chain and various supply chain processes and describe the concept of Bullwhip effect and how it can be prevented.
- Differentiate between inbound and outbound logistics and Explain theoretically MRP and MRP II, JIT, ERP, DRP, DRP II.
- Describe in detail the role of customer relationship management, the role of IT in supply chain, supply chain IT framework and coordination in supply chain.
- Describe and demonstrate the supplier selection process and sourcing decisions in a supply chain explaining the role and importance of sourcing and supplier relationship management.
- Describe in detail the decisions related to in-house logistics management or outsourcing the logistics to third party or fourth party logistics provider.
- Describe in detail the aspects related to green supply chain management and sustainability in supply chain along with the concepts of lean manufacturing and agile supply chain.
- Demonstrate the application of supply chain analytics which includes descriptive, predictive and prescriptive analytics.

Syllabus of GE-7(b):

Unit I: Introduction to Supply Chain and Supply Chain Networks (10 hours)

Basics concepts of supply chain and value chain, Evolution of supply chain, Supply chain integration, Important elements of supply chain, Inbound and outbound logistics, Supply chain processes, Introduction to supply chain network, Factors influencing supply chain network, Designing the supply chain network, Framework for structuring a supply chain, Transportation network design.

Unit II: Planning and Control in Supply Chain Operations (11 hours)

Planning and inventory management, MRP, MRP-II, JIT, ERP, DRP, DRP-II, Facility location, Customer relationship management, Role of IT in supply chain, Supply chain IT framework, Supply chain coordination, Bullwhip effect.

Unit III: Procurement and Strategic Sourcing in Supply Chain Management (12 hours)
Procurement management, Selection and management of suppliers, Supplier relationship management, Sourcing decisions in a supply chain, Role of sourcing in SC, Third- and Fourth-Party Logistics.

Unit IV: Sustainable, Lean, Agile, and Data-Driven Supply Chain Management (12 hours)
Global supply chain, Reverse supply chain, Closed loop supply chain, Green supply chain, Sustainability in supply chain, Lean Manufacturing and Agile supply chain, Supply chain analytics: descriptive, predictive and prescriptive analytics.

Suggestive Tutorial Activities: (15 hours)

1. Exercises on facility location, transportation network design.
2. Case-based analysis on sourcing, supply chain coordination, and distribution strategies.
3. Practice on implementation of MRP, MRP-II, JIT, ERP, DRP, DRP-II,
4. Student presentations on supply chain practices in real life.
5. Software Exercises: Solving facility location problems and supplier selection problems with Excel Solver/Python.

Practical component (if any) - Nil

Essential Readings:

1. Chopra S., & Meindl, P. (2014). *Supply chain management: strategy, planning, and operation* (6th ed.). Pearson Education India: India.
2. Gupta, S. M. (2013). *Reverse supply chains: issues and analysis*. USA: CRC Press.
3. Mentzer, J. T. (2004). *Fundamentals of supply chain management: twelve drivers of competitive advantage*. USA: Sage publications.
4. Ravindran, A. R., & Warsing Jr., D. P. (2012). *Supply chain engineering: models and applications*. USA: CRC Press.
5. Rushton, P., Croucher, P., & Baker P. (2014). *The handbook of logistics and distribution management: understanding the supply chain*. UK: Kogan Page Publishers.
6. Simchi-Levi, D. (2005). *Designing and managing the supply chain*. USA: McGraw-Hill.
7. Sople, V. V. (2011). *Supply chain management: text and cases*. India: Pearson Education India.
8. Wang, H. F., & Gupta, S. M. (2011). *Green supply chain management: product life cycle approach*. USA: McGraw Hill Professional.

Suggested Readings: Nil

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

OPERATIONAL RESEARCH

COURSES OFFERED BY DEPARTMENT OF OPERATIONAL RESEARCH

Category I

Operational Research Courses for Undergraduate Programme of Study with Operational Research as a Single Core Discipline

(B.Sc. Honours in Operational Research Course in four years)

STRUCTURE OF EIGHTH SEMESTER

DISCIPLINE SPECIFIC CORE COURSE – 20: LOGISTICS AND SUPPLY CHAIN 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		
Logistics and Supply Chain Management (DSC-20)	4	3	1	0	-	Nil

Learning Objectives:

- To impart the knowledge of concepts and approaches for supply chain management.
- To tackle the issues and problems related to the management of demand and supply of goods and services.
- To develop skills which helps in understanding how the theories relate to practice.

Learning Outcomes:

Students completing this course will be able to:

- Explain the theoretical terminologies related to supply chain management.
- Differentiate between inbound and outbound logistics and explain concepts of MRP and MRP II, JIT, ERP, DRP, DRP II.
- Describe in detail the role of customer relationship management, the role of IT in supply chain, supply chain IT framework and coordination in supply chain.
- Describe and demonstrate the supplier selection process and sourcing decisions in a supply chain.
- Describe in detail the decisions related to in-house logistics management or outsourcing the logistics to third party or fourth party logistics provider.
- Describe in detail the aspects related to green supply chain management and sustainability in supply chain along with the concepts of lean manufacturing and agile supply chain.
- Demonstrate the application of supply chain analytics.

Syllabus of DSC-20:

Unit I: Introduction to Supply Chain and Supply Chain Networks (10 hours)
Basics concepts of supply chain and value chain, Evolution of supply chain, Supply chain integration, Important elements of supply chain, Inbound and outbound logistics, Supply chain processes, Introduction to supply chain network, Factors influencing supply chain network, Designing the supply chain network, Framework for structuring a supply chain, Transportation network design.

Unit II: Planning and Control in Supply Chain Operations (11 hours)
Planning and inventory management, MRP, MRP-II, JIT, ERP, DRP, DRP-II, Facility location, Customer relationship management, Role of IT in supply chain, Supply chain IT framework, Supply chain coordination, Bullwhip effect.

Unit III: Procurement and Strategic Sourcing in Supply Chain Management (12 hours)
Procurement management, Selection and management of suppliers, Supplier relationship management, Sourcing decisions in a supply chain, Role of sourcing in SC, Third- and Fourth- Party Logistics.

Unit IV: Sustainable, Lean, Agile, and Data-Driven Supply Chain Management (12 hours)
Global supply chain, Reverse supply chain, Closed loop supply chain, Green supply chain, Sustainability in supply chain, Lean Manufacturing and Agile supply chain, Supply chain analytics: descriptive, predictive and prescriptive analytics.

Suggestive Tutorial Activities: (15 hours)

1. Exercises on facility location, transportation network design.
2. Case-based analysis on sourcing, supply chain coordination, and distribution strategies.
3. Practice on implementation of MRP, MRP-II, JIT, ERP, DRP, DRP-II,
4. Student presentations on supply chain practices in real life.
5. Software Exercises: Solving facility location problems and supplier selection problems with Excel Solver/Python.

Practical component (if any) - Nil

Essential Readings:

1. Chopra S., & Meindl, P. (2014). Supply chain management: strategy, planning, and operation (6th ed.). Pearson Education India: India.
2. Gupta, S. M. (2013). Reverse supply chains: issues and analysis. USA: CRC Press.
3. Mentzer, J. T. (2004). Fundamentals of supply chain management: twelve drivers of competitive advantage. USA: Sage publications.
4. Ravindran, A. R., & Warsing Jr., D. P. (2012). Supply chain engineering: models and applications. USA: CRC Press.
5. Rushton, P., Croucher, P., & Baker P. (2014). The handbook of logistics and distribution management: understanding the supply chain. UK: Kogan Page Publishers.
6. Simchi-Levi, D. (2005). Designing and managing the supply chain. USA: McGraw-Hill.
7. Sople, V. V. (2011). Supply chain management: text and cases. India: Pearson Education India.
8. Wang, H. F., & Gupta, S. M. (2011). Green supply chain management: product life cycle approach. USA: McGraw Hill Professional.

Suggested Readings: Nil

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

Category II

Operational Research Courses for Undergraduate Programme of Study with Operational Research as one of the Core Disciplines

(B.A. Programme with Operational Research as Major Discipline)

DISCIPLINE SPECIFIC CORE COURSE – 14: LOGISTICS AND SUPPLY CHAIN 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		
Logistics and Supply Chain Management (DSC-14)	4	3	1	0	-	Nil

Learning Objectives:

- To impart the knowledge of concepts and approaches for supply chain management.
- To tackle the issues and problems related to the management of demand and supply of goods and services.
- To develop skills which helps in understanding how the theories relate to practice.

Learning Outcomes:

Students completing this course will be able to:

- Explain the theoretical terminologies related to supply chain management.
- Differentiate between inbound and outbound logistics and explain concepts of MRP and MRP II, JIT, ERP, DRP, DRP II.
- Describe in detail the role of customer relationship management, the role of IT in supply chain, supply chain IT framework and coordination in supply chain.
- Describe and demonstrate the supplier selection process and sourcing decisions in a supply chain.
- Describe in detail the decisions related to in-house logistics management or outsourcing the logistics to third party or fourth party logistics provider.
- Describe in detail the aspects related to green supply chain management and sustainability in supply chain along with the concepts of lean manufacturing and agile supply chain.
- Demonstrate the application of supply chain analytics.

Syllabus of DSC-14:

Unit I: Introduction to Supply Chain and Supply Chain Networks (10 hours)
Basics concepts of supply chain and value chain, Evolution of supply chain, Supply chain integration, Important elements of supply chain, Inbound and outbound logistics, Supply chain processes, Introduction to supply chain network, Factors influencing supply chain network, Designing the supply chain network, Framework for structuring a supply chain, Transportation network design.

Unit II: Planning and Control in Supply Chain Operations (11 hours)
Planning and inventory management, MRP, MRP-II, JIT, ERP, DRP, DRP-II, Facility location, Customer relationship management, Role of IT in supply chain, Supply chain IT framework, Supply chain coordination, Bullwhip effect.

Unit III: Procurement and Strategic Sourcing in Supply Chain Management (12 hours)
Procurement management, Selection and management of suppliers, Supplier relationship management, Sourcing decisions in a supply chain, Role of sourcing in SC, Third- and Fourth- Party Logistics.

Unit IV: Sustainable, Lean, Agile, and Data-Driven Supply Chain Management (12 hours)
Global supply chain, Reverse supply chain, Closed loop supply chain, Green supply chain, Sustainability in supply chain, Lean Manufacturing and Agile supply chain, Supply chain analytics: descriptive, predictive and prescriptive analytics.

Suggestive Tutorial Activities: (15 hours)

1. Exercises on facility location, transportation network design.
2. Case-based analysis on sourcing, supply chain coordination, and distribution strategies.
3. Practice on implementation of MRP, MRP-II, JIT, ERP, DRP, DRP-II,
4. Student presentations on supply chain practices in real life.
5. Software Exercises: Solving facility location problems and supplier selection problems with Excel Solver/Python.

Practical component (if any) - Nil

Essential Readings:

1. Chopra S., & Meindl, P. (2014). Supply chain management: strategy, planning, and operation (6th ed.). Pearson Education India: India.
2. Gupta, S. M. (2013). Reverse supply chains: issues and analysis. USA: CRC Press.
3. Mentzer, J. T. (2004). Fundamentals of supply chain management: twelve drivers of competitive advantage. USA: Sage publications.
4. Ravindran, A. R., & Warsing Jr., D. P. (2012). Supply chain engineering: models and applications. USA: CRC Press.
5. Rushton, P., Croucher, P., & Baker P. (2014). The handbook of logistics and distribution management: understanding the supply chain. UK: Kogan Page Publishers.
6. Simchi-Levi, D. (2005). Designing and managing the supply chain. USA: McGraw-Hill.
7. Sople, V. V. (2011). Supply chain management: text and cases. India: Pearson Education India.
8. Wang, H. F., & Gupta, S. M. (2011). Green supply chain management: product life cycle approach. USA: McGraw Hill Professional.

Suggested Readings: Nil

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

Category III

Operational Research Courses for Undergraduate Programme of Study with Operational Research as one of the Core Disciplines

(B.A. Programme with Operational Research as non-Major or Minor Discipline)

DISCIPLINE SPECIFIC CORE COURSE – 8: LOGISTICS AND SUPPLY CHAIN 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		
Logistics and Supply Chain Management (DSC-8)	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

- To impart the knowledge of concepts and approaches for supply chain management.
- To tackle the issues and problems related to the management of demand and supply of goods and services.
- To develop skills which helps in understanding how the theories relate to practice.

Learning Outcomes:

Students completing this course will be able to:

- Explain the theoretical terminologies related to supply chain management.
- Differentiate between inbound and outbound logistics and explain concepts of MRP and MRP II, JIT, ERP, DRP, DRP II.
- Describe in detail the role of customer relationship management, the role of IT in supply chain, supply chain IT framework and coordination in supply chain.
- Describe and demonstrate the supplier selection process and sourcing decisions in a supply chain.
- Describe in detail the decisions related to in-house logistics management or outsourcing the logistics to third party or fourth party logistics provider.
- Describe in detail the aspects related to green supply chain management and sustainability in supply chain along with the concepts of lean manufacturing and agile supply chain.
- Demonstrate the application of supply chain analytics.

Syllabus of DSC-8:

Unit I: Introduction to Supply Chain and Supply Chain Networks (10 hours)
Basics concepts of supply chain and value chain, Evolution of supply chain, Supply chain integration, Important elements of supply chain, Inbound and outbound logistics, Supply chain processes, Introduction to supply chain network, Factors influencing supply chain network, Designing the supply chain network, Framework for structuring a supply chain, Transportation network design.

Unit II: Planning and Control in Supply Chain Operations (11 hours)
Planning and inventory management, MRP, MRP-II, JIT, ERP, DRP, DRP-II, Facility location, Customer relationship management, Role of IT in supply chain, Supply chain IT framework, Supply chain coordination, Bullwhip effect.

Unit III: Procurement and Strategic Sourcing in Supply Chain Management (12 hours)
Procurement management, Selection and management of suppliers, Supplier relationship management, Sourcing decisions in a supply chain, Role of sourcing in SC, Third- and Fourth- Party Logistics.

Unit IV: Sustainable, Lean, Agile, and Data-Driven Supply Chain Management (12 hours)
Global supply chain, Reverse supply chain, Closed loop supply chain, Green supply chain, Sustainability in supply chain, Lean Manufacturing and Agile supply chain, Supply chain analytics: descriptive, predictive and prescriptive analytics.

Suggestive Tutorial Activities: (15 hours)

1. Exercises on facility location, transportation network design.
2. Case-based analysis on sourcing, supply chain coordination, and distribution strategies.
3. Practice on implementation of MRP, MRP-II, JIT, ERP, DRP, DRP-II,
4. Student presentations on supply chain practices in real life.
5. Software Exercises: Solving facility location problems and supplier selection problems with Excel Solver/Python.

Practical component (if any) - Nil

Essential Readings:

1. Chopra S., & Meindl, P. (2014). Supply chain management: strategy, planning, and operation (6th ed.). Pearson Education India: India.
2. Gupta, S. M. (2013). Reverse supply chains: issues and analysis. USA: CRC Press.
3. Mentzer, J. T. (2004). Fundamentals of supply chain management: twelve drivers of competitive advantage. USA: Sage publications.
4. Ravindran, A. R., & Warsing Jr., D. P. (2012). Supply chain engineering: models and applications. USA: CRC Press.
5. Rushton, P., Croucher, P., & Baker P. (2014). The handbook of logistics and distribution management: understanding the supply chain. UK: Kogan Page Publishers.
6. Simchi-Levi, D. (2005). Designing and managing the supply chain. USA: McGraw-Hill.
7. Sople, V. V. (2011). Supply chain management: text and cases. India: Pearson Education India.
8. Wang, H. F., & Gupta, S. M. (2011). Green supply chain management: product life cycle approach. USA: McGraw Hill Professional.

Suggested Readings: Nil

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

Category IV

B.Sc. Physical Sciences/ Mathematical Sciences with Operational Research as one of the three Core Disciplines
CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

DISCIPLINE SPECIFIC CORE COURSE – 8:
LOGISTICS AND SUPPLY CHAIN 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		
Logistics and Supply Chain Management (DSC-8)	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

- To impart the knowledge of concepts and approaches for supply chain management.
- To tackle the issues and problems related to the management of demand and supply of goods and services.
- To develop skills which helps in understanding how the theories relate to practice.

Learning Outcomes:

Students completing this course will be able to:

- Explain the theoretical terminologies related to supply chain management.
- Differentiate between inbound and outbound logistics and explain concepts of MRP and MRP II, JIT, ERP, DRP, DRP II.
- Describe in detail the role of customer relationship management, the role of IT in supply chain, supply chain IT framework and coordination in supply chain.
- Describe and demonstrate the supplier selection process and sourcing decisions in a supply chain.
- Describe in detail the decisions related to in-house logistics management or outsourcing the logistics to third party or fourth party logistics provider.
- Describe in detail the aspects related to green supply chain management and sustainability in supply chain along with the concepts of lean manufacturing and agile supply chain.
- Demonstrate the application of supply chain analytics.

Syllabus of DSC-8

Unit I: Introduction to Supply Chain and Supply Chain Networks (10 hours)
Basics concepts of supply chain and value chain, Evolution of supply chain, Supply chain integration, Important elements of supply chain, Inbound and outbound logistics, Supply chain processes, Introduction to supply chain network, Factors influencing supply chain network, Designing the supply chain network, Framework for structuring a supply chain, Transportation network design.

Unit II: Planning and Control in Supply Chain Operations (11 hours)
Planning and inventory management, MRP, MRP-II, JIT, ERP, DRP, DRP-II, Facility location, Customer relationship management, Role of IT in supply chain, Supply chain IT framework, Supply chain coordination, Bullwhip effect.

Unit III: Procurement and Strategic Sourcing in Supply Chain Management (12 hours)
Procurement management, Selection and management of suppliers, Supplier relationship management, Sourcing decisions in a supply chain, Role of sourcing in SC, Third- and Fourth- Party Logistics.

Unit IV: Sustainable, Lean, Agile, and Data-Driven Supply Chain Management (12 hours)
Global supply chain, Reverse supply chain, Closed loop supply chain, Green supply chain, Sustainability in supply chain, Lean Manufacturing and Agile supply chain, Supply chain analytics: descriptive, predictive and prescriptive analytics.

Suggestive Tutorial Activities: (15 hours)

1. Exercises on facility location, transportation network design.
2. Case-based analysis on sourcing, supply chain coordination, and distribution strategies.
3. Practice on implementation of MRP, MRP-II, JIT, ERP, DRP, DRP-II,
4. Student presentations on supply chain practices in real life.
5. Software Exercises: Solving facility location problems and supplier selection problems with Excel Solver/Python.

Practical component (if any) - Nil

Essential Readings:

1. Chopra S., & Meindl, P. (2014). Supply chain management: strategy, planning, and operation (6th ed.). Pearson Education India: India.
2. Gupta, S. M. (2013). Reverse supply chains: issues and analysis. USA: CRC Press.
3. Mentzer, J. T. (2004). Fundamentals of supply chain management: twelve drivers of competitive advantage. USA: Sage publications.
4. Ravindran, A. R., & Warsing Jr., D. P. (2012). Supply chain engineering: models and applications. USA: CRC Press.
5. Rushton, P., Croucher, P., & Baker P. (2014). The handbook of logistics and distribution management: understanding the supply chain. UK: Kogan Page Publishers.
6. Simchi-Levi, D. (2005). Designing and managing the supply chain. USA: McGraw-Hill.
7. Sople, V. V. (2011). Supply chain management: text and cases. India: Pearson Education India.
8. Wang, H. F., & Gupta, S. M. (2011). Green supply chain management: product life cycle approach. USA: McGraw Hill Professional.

Suggested Readings: Nil

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

CATEGORY-V

B.Sc. (H) Operational Research / B.A. Programme with Operational Research as Major Discipline/ B.A. Programme with Operational Research as non-Major or Minor Discipline Minor/B.Sc. (Physical Sciences/Mathematical Sciences) with OR as one of the three core Disciplines
COMMON POOL OF DISCIPLINE SPECIFIC ELECTIVES (DSE) offered by the parent Department, i.e., Department of Operational Research

DISCIPLINE SPECIFIC ELECTIVE (DSE-6(a): APPLIED MATHEMATICAL MODELLING)

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 Mathematical Modelling (DSE-6(a))	4	3	0	1	-	Nil

Learning Objectives:

The Learning Objectives of this course are as follows:

- To introduce the students to the exciting world of Differential Equations, Mathematical Modelling, and their applications.
- To develop a broad understanding of mathematical theory, concepts and applications.
- To explain the utility of differential equations for understanding real-life scenarios.
- To explain the purpose, concept, and methodology behind the mathematical modelling framework.

Learning Outcomes:

Students completing this course will be able to:

- Understand concepts, issues, and applications of mathematical modelling.
- Formulate Differential Equations for various real-life scenarios via mathematical models.
- Solve first-order non-linear differential equations and linear differential equations of higher order using various techniques.
- Apply these techniques to solve and analyze various mathematical models.
- understand the nature of deterministic mathematical modelling, including model formulation, selection of appropriate mathematical formalism, solution strategies and interpretation of results.

Syllabus of DSE-6(a):

Unit I: An Introduction to Mathematical Modeling (5 hours)
Definition and Importance of Mathematical Modeling, Types of Models: Physical, Mathematical, Statistical, and Simulation Models, Steps in Mathematical Modeling Process, Limitations and Validation of Models

Unit II: Differential Equations based Mathematical Modelling (15 hours)
Overview of mathematical modelling, Types of mathematical models and methods to solve the same; Differential equations and mathematical models, Order and degree of a differential equation, Exact differential equations and integrating factors of first-order differential equations, Reducible second-order differential equations, Application of first-order differential equations to equations to acceleration-velocity model, Growth and decay model.

Unit III: Understanding Compartmental Modeling (15 hours)
Introduction to compartmental models, General solution of the homogeneous equation of second order, Principle of superposition for a homogeneous equation; Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, introduction to epidemic modelling framework

Unit IV: An Operational Research Perspective of Differential Equations (10 hours)
Application of first-order and second-order differential equations in marketing management, decision science, reliability theory, and other OR domains

Suggestive Tutorial Activities: Nil

Practical component (if any) – **(30 hours)**

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

1. Plotting of the second and third order respective solution families of the differential equation.
2. Growth and decay model (exponential case only).
3. Lake pollution model (with constant/seasonal flow and pollution concentration).
4. Predatory-prey model (basic Volterra model, with density dependence, effect of DDT, two prey, one predator).
5. Epidemic model of influenza (basic epidemic model, contagious for life, disease with carriers).

Essential Readings:

1. Barnes, Belinda & Fulford, Glenn R. (2015). Mathematical Modelling with Case Studies, Using Maple and MATLAB (3rd ed.). CRC Press, Taylor & Francis Group.
2. Edwards, C. Henry, Penney, David E., & Calvis, David T. (2015). Differential Equation and Boundary Value Problems: Computing and Modelling (5th ed.). Pearson Education.
3. Ross, Shepley L. (2004). Differential Equations (3rd ed.). John Wiley & Sons. India

Suggested Readings:

1. Giordano, F. R., Fox W. P., and Horton S. B. (2014), A first course in mathematical modeling, Brooks/Cole.
2. Mesterton-Gibbons, M. (2007). A concrete approach to mathematical modeling. Addison- Wesley.
3. Strogatz, S. (1994). Nonlinear dynamics and chaos. Westview 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-6(b): BUSINESS ANALYTICS FOR MANAGEMENT DECISIONS)

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		
Business Analytics for Management Decisions DSE-6(b)	**4**	**3**	**0**	**1**	**-**	**Nil**

Learning Objectives:

The Learning Objectives of this course are as follows:

- To raise awareness of Business Analytics among students and make them understand the application of business analytics in an organization.
- To acquaint them with necessary technical skills to support business decision-making and relevance and usefulness of business analytics solutions.

Learning Outcomes:

Students completing this course will be able to:

- Gain an understanding of basic concepts of Business Analytics and differentiate between them.
- Apply various techniques of business analytics in real-life scenarios.
- Interpret the effectiveness of business analytics solutions.
- Support business decision-making using relevant business analytics methods.

Syllabus of DSE-6(b):

Unit I: Introduction to Business Analytics: (7 hours)
Concept and application areas, roles and responsibilities of business analysts, an overview of techniques of business analytics, usefulness of data for business analytics, understanding data, data collection, data cleaning and preparation, data visualization, data-driven decision making.

Unit II: Database and Data-warehouse (10 hours)
Introduction to Database Management System, Advantages of DBMS over file-based system, 3-level architecture, Relational databases and SQL, Database vs. Data Warehouse, Overview of Data Mining.

Unit III: Predictive Analytics and Time Series Analysis (18 hours)
An introduction to regression analysis, Simple Linear Regression model: meaning, hypothesis testing, confidence interval, coefficient of determination, Decision Tree: meaning, examples and application. Introduction to time series, Components of time series: Trend, Seasonal, Cyclical and Irregular. Measure of Trend, seasonality and cyclic component. Exponential Smoothing: Single Exponential Smoothing.

Unit IV: Mathematical Optimization for Business (10 hours)
An Introduction to Linear Programming, Graphical Solution, Simplex method, Sensitivity Analysis, Introduction to Simulation, Monte Carlo Simulation technique.

Suggestive Tutorial Activities: Nil

Practical component (if any) - (30 hours)

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

1. Using DDL commands of create table, alter table, drop table.
2. Utilization of DML commands of select, insert, update, delete.
3. Understanding of condition specification using Boolean and comparison operators (AND, OR =, >, < etc.).
4. Utility of arithmetic operators and aggregate functions (COUNT, SUM, AVG etc.).
5. Fitting a simple linear regression model.
6. Construction and visualization of Decision Tree.
7. Plot and visualize time series data.
8. Measurement of components of time series.
9. Solution of a Linear Programming Problem.
10. Application of Monte Carlo Simulation.

Essential Readings:

1. Camm, J. D., Cochran, J. J., Fry, M. J., Ohlmann, J. W., Anderson, D. R., Sweeney, D. J., & Williams, T. A. (2015). Essentials of business analytics. Stamford, CT, USA: Cengage Learning.
2. Elmasri, R., & Navathe, S. B. (2017). Fundamentals of Database Systems 7th Edition. Pearson Education
3. Gujarati, D. N. (2021). Essentials of econometrics. Sage Publications.
4. Makridakis, S., Wheelwright, S. C., & Hyndman, R. J. (2008). Forecasting methods and applications. John wiley & sons.
5. Hillier, F. S., & Lieberman, G. J. (2015). Introduction to operations research. McGraw- Hill.
6. Taha, H. A., & Taha, H. A. (2003). Operations research: an introduction (Vol. 7). Upper Saddle River, NJ: Prentice hall.

Suggested Readings:

1. Jank, W. (2011). Business analytics for managers. Springer Science & Business Media.
2. Sharda, R., Delen, D., & Turban, E. (2014). Business intelligence and analytics: systems for decision support. Pearson.
3. Date, C. J. (2003). Addison-Wesley, Introduction to Database Systems 8th Edition, Pearson Education.
4. Han, J., & Kamber, M. (2001). Data Mining: Concepts and Techniques, Morgan Kaufmann Publishers.
5. Pindyck, R. S., & Rubinfeld, D. L. (1976). Econometric models and economic forecasts. McGraw-Hill.

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

DISCIPLINE SPECIFIC ELECTIVE
(DSE-6(c): INTRODUCTION TO PRICING AND REVENUE OPTIMIZATION)

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		
Introduction to Pricing and Revenue Optimization (DSE-6(c))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The Learning Objectives of this course are as follows:

- To make students understand the different pricing principles and the revenue management concept.
- To acquaint them with optimization models of revenue management and their application across different industries.

Learning Outcomes:

Students completing this course will be able to:

- Understand the introductory pricing and revenue optimization problem.
- Gain an understanding of the economics of price differentiation and market segmentation.
- Comprehend the revenue management system and the factors affecting the system.
- Develop and solve mathematical models for revenue optimization.
- Identify the applications of revenue management to different industries.

Syllabus of DSE-6(c):

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

History of Pricing and Revenue Optimization. Strategies of Price Optimization. Basic Price Optimization: The Price-Response Function, measures of Price sensitivity: slope and elasticity, Price Response with Competition, The Basic Price Optimization Problem.

Unit II: Price Differentiation & Constrained Supply **(11 hours)**

Price Differentiation: The Economics of Price Differentiation, Limits to Price Differentiation, Tactics for Price Differentiation, Volume Discounts. Pricing with Constrained Supply: The Nature of Supply Constraints, Optimal Pricing with a Supply Constraint.

Unit III: Revenue Management **(12 hours)**

Conceptual framework of revenue management: levels of RM, strategy for RM, booking control. Revenue management system. Demand-management decisions. Factors affecting revenue management. Role of revenue management in various industries. Single resource capacity control: types of control, Littlewood's two-class model.

Unit IV: Capacity allocation **(12 hours)**

Capacity allocation for multiple resources, i.e. network management. Applicability of network RM, types of networks. Network RM via Linear Programming approach. Introduction to Overbooking models: overbooking based on service criteria; overbooking based on economic criteria (simple risk-based booking limit model).

Suggestive Tutorial Activities: **(15 hours)**

1. Price Optimization problems with varying price response functions.
2. Problems based on price differentiation and market segmentation
3. Overbooking and capacity allocation problems.
4. Linear Programming formulation for Network RM.
5. Case analysis of pricing strategies in airlines, hotels, and e-commerce.
6. Software Exercises: Price optimization and Revenue modeling using Excel / R.

Practical component (if any): Nil

Essential Readings:

1. Phillips, R. L. (2005). Pricing and revenue optimization. Stanford University Press.
2. Talluri, K. T., & Van Ryzin, G. J. (2006). The theory and practice of revenue management (Vol. 68). Springer Science & Business Media.
3. Cross, G. R. (1997). Revenue management: hard-core tactics for market domination. New York: Broadway Books.
4. Lilien, G. L., Kotler, P., & Moorthy, K. S. (1995). Marketing models. Prentice Hall.
5. Yeoman, I., & McMahon-Beattie, U. (Eds.). (2004). Revenue management and pricing: case studies and applications. Cengage Learning EMEA.

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-6(d): MULTIPLE OBJECTIVE OPTIMIZATION)

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		
Multiple Objective Optimization (DSE-6(d))	**4**	**3**	**1**	**0**	**--**	**Nil**

Learning Objectives:

The Learning Objectives of this course are as follows:

- To provide a comprehensive understanding of multi-objective optimization problems, focusing on classical methods in Operational Research.
- To equip students with the key concepts, mathematical foundations, and traditional techniques for analysing and solving multi-objective problems, emphasizing their applicability in various applications of Operational Research.

Learning Outcomes:

Students completing this course will be able to:

- Understand the theoretical principles of multi-objective optimization.
- Formulate multi-objective optimization problems using classical techniques.
- Understand Pareto optimality and trade-off analysis.
- Analyse the existence of solutions using fundamental principles.
- Implement classical algorithms for solving multi-objective optimization problems.
- Analyse the trade-off results of multi-objective optimization in real-world scenarios.

Syllabus of DSE-6(d):

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

Introduction to Multi-Objective Optimization Problem (MOOP). Definition and significance of MOOP and its comparison with a single-objective optimization problem. Basics of convexity and concavity in MOOP. Dominance relations, Pareto optimality and Weak Pareto Optimality. Multi-objective problem formulations with Applications in Operational Research.

Unit II: Optimality Conditions and Duality **(8 hours)**

Fritz-John and Karush-Kuhn-Tucker necessary and sufficient optimality conditions for Pareto optimality. Duality concepts in MOOP. Weak and strong duality results using Wolfe's dual.

Unit III: Scalarization Methods **(14 hours)**

Introduction to scalarization techniques for MOOP. Weighted sum method: theory and applications. ε-constraint method: theory and applications. Lexicographic optimization. Goal programming: setting goals and trade-off analysis. Comparative analysis of scalarization methods based on their benefits and limitations. Constructing the Pareto frontier. Characterization and interpretation of Pareto optimal solutions. Visualizing trade-offs through graphical representation.

Unit IV: Interactive Approaches and Cases **(14 hours)**

Introduction to interactive methods for decision-making. User preferences in generating solutions. Tchebycheff method. Weighted Tchebycheff method. Formulation of multi- objective linear programming and integer programming problems. Cases in manufacturing, service sector, transportation and logistics optimization, financial and environmental applications.

Suggestive Tutorial Activities: **(15 hours)**

1. Formulation and analysis of multi-objective optimization problems with real-world relevance in operations research.
2. Application of scalarization techniques (weighted sum, ε-constraint, goal programming) to solve multi-objective optimization problems.
3. Graphical interpretation of Pareto frontiers and evaluation of trade-offs using case- based scalarization methods.
4. Modeling and solving multi-objective linear and integer programming problems across sectors like manufacturing, logistics, finance, and environment.
5. Use of software tools for solving multi-objective optimization problems.

Practical component (if any) – Nil

Essential Readings:

1. Fran Sérgio Lobato & Valder Steffen Jr (2017). Multi-Objective Optimization Problems: Concepts and Self-Adaptive Parameters with Mathematical and Engineering Applications. Springer.
2. Panos M. Pardalos, Antanas Žilinskas & Julius Žilinskas (2017). Non-Convex Multi- Objective Optimization. Springer Optimization and Its Applications, Volume 123, Springer.
3. Ralph E. Steuer (1986). Multiple Criteria Optimization: Theory, Computation and Application. Wiley Series in Probability and Mathematical Statistics-Applied, Wiley.
4. Matthias Ehrgott (2005). Multicriteria Optis and applications. Cengage Learning EMEA.

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-6(e): RELIABILITY TESTING)

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		
Reliability Testing (DSE-6(e))	**4**	**3**	**1**	**0**	**-**	**Nil**

Learning Objectives:

The Learning Objectives of this course are as follows:

- To teach life data and degradation data analyses that can help in Engineering Management during Design and Development Phase, Design Verification Phase and Process Validation Phase of a product (electrical, electronic and mechanical, software) life cycle.
- To teach how to find whether the reliability of a given device (system) at a certain age is sufficiently high. How many test items to be tested for this purpose?
- To teach how to model Accelerated Life Tests
- The students will be familiar with the software development process concepts, various life cycles and reliability assessment.

Learning Outcomes:

Students completing this course will be able to:

- Learn life data and degradation data analytic techniques in industries that manufacture electrical, electronic, mechanical, and software items.
- To find out if a product has met a certain reliability requirement with a specific confidence.
- To model testing and planning of lifetime data sets in accelerated environmental conditions
- Comprehend various software testing approaches.
- Understand about the mathematical models for software reliability assessment and prediction

Syllabus of DSE-6(e):

Unit I: Life data analysis **(10 hours)**

Product Life Cycle, Integrating reliability into product's life cycle, Reliability tasks for a typical product life cycle, Reliability Metrics, Product's Life distributions, Hard Failure and Soft Failure, Life data analysis with complete, time-censored, and failure censored data sets, Degradation data, Relation of Degradation to Failure, Degradation Modelling: Data-Driven Models; Models based on Stochastic Processes (Wiener and Gamma Processes).

Unit I1: Hardware Reliability Testing **(12 hours)**

Reliability Verification Testing – Verification Testing, Success Testing, Success- Failure Testing, Testing to Failure, Exponential Test Planning, Weibull Test Planning. Accelerated Tests(ATs)- Need for Accelerated Tests, Types of Accelerated Tests: Accelerated Life Tests (ALTs) and Accelerated Degradation Tests (ADTs), Types of Stress Schemes-Constant-Stress; Step-Stress; Progressive Stress; Cyclic Stress; Random Stress; and their various combinations, Stress- Life Relationships, Acceleration Factor, ALT Test Plans.

Unit III: Software Testing and its Levels **(11 hours)**

Software Development Life Cycle (SDLC), Software Testing, Advantages and Challenges in Software Testing. Verification and Validation (V & V), code inspection, Test Cases, Test Plans, and Test Strategies. Software Testing Techniques: Static Testing, Dynamic Testing, Black Box Testing, White Box Testing. Levels of Testing: Unit Testing, Integration, System Testing, and Acceptance Testing. Functional vs. Non-functional Testing. Cost related to testing.

Unit IV: Software Reliability Models **(12 hours)**

Introduction to Software Reliability and its usage in the Testing Phase, Difference of Hardware and Software Reliability, Musa's Basic execution time model, Jelinski-Moranda Model a Infinite Failure Category Model: Duane's Model. Non-homogeneous Poisson Process-based modeling (exponential and S-shaped).

Suggestive Tutorial Activities: **(15 hours)**

1. Problems related to life data analysis using complete and censored data sets with exponential and Weibull life distributions.
2. Degradation Data Analysis Using Wiener and Gamma Processes.
3. Case studies on accelerated testing with constant and step-stress loadings
4. Mathematical modeling using NHPP.
5. Use of software tools for solving hardware and software reliability models

Practical component (if any) - Nil

Essential Readings:

1. Hφyland, A. and M. Rausand (2004). System Reliability Theory: Models and Statistical Methods, 2nd edition John Wiley & Sons Inc., Hobokens, New Jersey.
2. Nelson, W.B. (1990). Accelerated Testing: Statistical Models, Test Plans, and Data Analysis, John Wiley & Sons Inc., Hoboken, New Jersey.
3. Wasserman,G.S. (2003). Reliability Verification and Testing in Engineering Designs, Marcel Dekker Inc., New York.
4. Yang, G. (2007). Life Cycle Reliability Engineering, John Wiley & Sons, Inc., Hoboken, New Jersey
5. Kapur, P. K., Pham, H., Gupta, A., & Jha, P. C. (2011). Software reliability assessment with OR applications (Vol. 364). London: Springer.
6. Aggarwal, K. K., & Singh Y. (2005). Software engineering, New Age International.
7. Pressman, R. S. (2005). Software engineering: a practitioner's approach. Palgrave Macmillan.
8. 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.

DISCIPLINE SPECIFIC ELECTIVE
(DSE-6(f): SOFT COMPUTING METHODS)

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 Methods (DSC-6(f))	4	3	0	1	-	Nil

Learning Objectives:

The Learning Objectives of this course are as follows:
- Familiarize with soft computing concepts.
- Introduce and use the concepts of Neural Networks, Fuzzy Logic and Genetic Algorithm.

Learning Outcomes:

Upon successful completion of this course the student will be able to:
- Identify and describe soft computing techniques and their roles in building intelligent machines.
- Understand and apply artificial Neural Networks in real life applications.
- Apply fuzzy logic and reasoning to handle uncertainty and solve various decision-making problems.
- Apply genetic algorithms to combinatorial optimization problems.

Syllabus of DSC-6(f):

Unit I: Introduction to Soft Computing **(7 hours)**
Soft Computing: Definition, History, Conception and Importance, Soft computing versus Hard computing, Some applications of soft computing techniques. Introduction to Fuzzy Computing, Evolutionary Computing: Genetic Algorithms, Genetic Programming and Neural Computing.

Unit II: Fuzzy Computing **(14 hours)**
Fuzzy Set theory, Fuzzy versus Crisp set, Fuzzy Relation, Fuzzification, Minmax Composition, Defuzzification Method, Fuzzy Logic, Fuzzy Rule based systems, Predicate logic, Fuzzy Decision Making, Fuzzy Control, Fuzzy Classification.

Unit III: Evolutionary Computing **(14 hours)**
Genetic Algorithm: Basic GA framework and different GA architectures, Fitness function GA operators: Encoding, Crossover, Selection, Mutation. Solving single-objective optimization problems using GA.

Unit IV: Applications **(10 hours)**

Application of Fuzzy Computing in stock market prediction, supply chain and Genetic Algorithm in Optimization: Travelling Salesman Problem, Vehicle routing problem.

Suggestive Tutorial Activities: Nil

Practical component (if any) – **(30 hours)**

Perform the following practical:

1. Write program to perform fuzzy set operations and properties.
2. Write program to define fuzzy sets and membership functions using MATLAB's Fuzzy Logic Toolbox.
3. Write a Program in MATLAB to Plot various Membership function**.**
4. Write program for Implementation of Fuzzy Inference System.
5. Write program to Implement Fuzzy Relations and apply Min-Max Composition in MATLAB.
6. Write program to Implement a Fuzzy Logic System with MATLAB's Fuzzy Logic Toolbox.
7. Write program to Define a fitness function to evaluate solutions.
8. Write program to apply Roulette Wheel Selection.
9. Write program to apply Tournament Selection.
10. Write program to apply single point and two-point crossover.
11. Write program to apply Bit Flip Mutation.
12. Write program to solve single-objective optimization problems using GA.
13. Write a program for maximizing $f(x) = x^2$ using GA. where x ranges from 0 to 31. Perform 5 iterations only.
14. Use Gatool and minimize the quadratic equation $f(x) = x^2 + 3x + 2$ within the range - 6<=x<=0
15. Write program for Traveling Salesman using GA.

Essential Readings:

1. Rajasekaran, S. Vijayalakshmi Pai (2003), Neural Networks, Fuzzy Logic and Genetic Algorithms: Synthesis & Applications, PHI Learning.
2. Sivanandam, S. N., & Deepa, S. N. (2007). Principles of soft computing (with CD). John Wiley & Sons.
3. Volna, E. (2020). Introduction to soft computing.
4. Klir, G., & Yuan, B. (2008). Fuzzy sets and fuzzy logic- Theory and Applications. Prentice hall.
5. Priddy L.K., Keller E.P (2005)., Artificial Neural Networks: An Introduction, SPIE Press.

Suggestive Readings:

1. Fausett, L. V. (2006). Fundamentals of neural networks: architectures, algorithms and applications. Pearson Education India.
2. Gen, M., & Cheng, R. (1999). Genetic algorithms and engineering optimization. John Wiley & Sons.
3. Ross, T. J. (2005). Fuzzy logic with engineering applications. John Wiley & Sons. MATLAB Toolkit Manual.

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

CATEGORY-VI

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES OFFERED BY THE DEPARTMENT

GENERIC ELECTIVE
(GE-8(a): 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-8(a)	4	3	1	0	-	Nil

Learning Objectives:

The Learning Objectives of this course are as follows:

- To impart knowledge of concepts related to quality management.
- To impart knowledge of popularly used tools for quality control and management of a plan.
- To develop practical skills for continuous quality improvement.

Learning Outcomes:

Students completing this course will be able to:

- Demonstrate understanding of total quality management philosophies, concepts, organization, practices, framework, and quality standards.
- Demonstrate understanding of quality management and problem-solving tools and techniques for product and process design.
- Apply statistical analysis tools for measuring and controlling quality.
- Illustrate use of process improvement methods and tools for process analysis and improvement to achieve performance excellence.
- Describe the concept and role of six sigma along with theoretical workings of the implementation of six sigma.

Syllabus of GE-8 (a):

Unit I: Introduction to Quality Management **(9 hours)**

Concept of quality management, History, evolution, and importance of quality in organizations, Concepts of product and service quality, Principles, practices and techniques of quality management, Philosophies and frameworks of quality given by various Quality Gurus.

Unit II: Tools and Techniques for Quality Improvement (11 hours)
Designing quality goods and services, Designing quality processes, Process control and improvement, Cost of quality, Tools: check sheet, flow charts, histograms, pareto analysis, Ishikawa diagram, scatter diagram, PDCA cycle.

Unit III: Statistical Quality Control (15 hours)
Variation, Causes of variations (natural and assignable), Measurement system analysis, Statistical process control, Process capability measurement, Control charts for variable: mean charts, range charts, Control charts for attributes: p-charts, np-charts, c-charts, u-charts, Product control, Acceptable quality level, Average outgoing quality, Average outgoing quality limit, OC curve, Consumers risk, Producers risk, Acceptable sampling plan: Single sampling plan, Double sampling plan, Sequential sampling plan.

Unit IV: Six Sigma (10 hours)
Introduction to six-sigma, Evolution of six-sigma, Principles of six-sigma, Statistical basis of 3.4 DPMO, Implementing six-sigma, Application of DMAIC, DMADV, Lean six-sigma and Lean six-sigma in services.

Suggestive Tutorial Activities: (15 hours)

1. Role based discussions on Principles, practices Philosophies of quality given by various Quality Gurus.
2. Statistical process control, DPMO practice exercises.
3. Application of quality tools and PDCA Cycle.
4. Presentations on case studies on TQM, Six Sigma, and continuous improvement.
5. Software Exercises: Developing histograms, Pareto analysis, scatter diagram; attribute and variable control Charts, Acceptance Sampling: Single and Double Sampling Plan in Excel.

Practical component (if any) – Nil

Essential Readings:

1. Charantimath, P. M. (2011). Total Quality Management. Pearson Education India: India.
2. Gupta, S. C., & Kapoor, V. K. (2009). Fundamentals of applied statistics. India: Sultan Chand & Sons.
3. Besterfield, D. H., Besterfield-Michna, C., Besterfield, G. H., Besterfield-Sacre, M., Urdhwareshe, H., & Urdhwareshe, R. (2014). Total Quality Management (5th ed.). Pearson Education India.

Suggested Readings:

1. Montgomery, D. C. (2009). Introduction to statistical quality control. New York: John Wiley & Sons.

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

GENERIC ELECTIVE
(GE-8(b): 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 (GE-8(b))	**4**	**3**	**0**	**1**	**---**	**Nil**

Learning Objectives:

The Learning Objectives of this course are as follows:

- To introduce the basic concepts of Software Engineering and related terminologies
- The students will be made familiar with the concepts of software development process, various life cycles and reliability assessment.
- To introduce various approaches for software project planning, Risk assessment & mitigation

Learning Outcomes:

Upon successful completion of this course the student will be able to:

- Understand software development life cycle, its various stages, and different approaches for software development projects.
- Know about Software Project management activities including planning, scheduling, risk management, etc.
- Comprehend various software testing approaches.
- Understand about the mathematical models for software reliability assessment and prediction
- Gain knowledge about tools and techniques of large-scale software systems development.

Syllabus of GE-8(b):

Unit I: Introduction **(12 hours)**

Software Scope, Software Development Challenges, Software Engineering Discipline, Software Methodologies and Software development life-cycle Models, Introduction to Agile Software Engineering.

Unit II: Software Requirement Management, System Design and Testing **(12 hours)**

Requirement Analysis and Modeling, Techniques, SRS: Needs, Characteristics and its Components, Design Principles, design specification, Cohesiveness and Coupling, Software Testing Fundamentals, , Software testing strategies, Validation Testing, System Testing, Black-Box Testing, White-Box Testing and their types.

Unit III: Software Project Management **(9 hours)**
Estimation in Project Planning Process, Project Scheduling, Software Risks, Risk Identification, Risk Projection and Risk Refinement, Risk mitigation, monitoring & management-The RMMM Plan

Unit IV: Understanding Software Reliability **(12 hours)**
Introduction to Software Reliability, Difference between Hardware and Software Reliability, Non-homogeneous Poisson Process based modeling, Software Quality Assurance, Quality Standards ISO 9000, Capability Maturity Model (CMM)

Suggestive Tutorial Activities: Nil

Practical component (if any) – **(30 hours)**

1. Problems related to Process Model
2. Problems related to Requirement Analysis
3. Problems related to Design Engineering
4. Problems related to Project Management
5. Problems related to Project Effort Estimation
6. Problems related to Project Risk Management
7. Problems related to Software Testing
8. Problems related to Software Quality Assurance
9. Software Reliability Prediction using mathematical models

Essential Readings:

1. Aggarwal, K. K., & Singh Y. (2005). Software engineering, New Age International.
2. Bell, D. (2005). Software Engineering for students. Pearson Education.
3. Jalote, P. (2012). An integrated approach to software engineering. Springer Science & Business Media.
4. Pressman, R. S. (2005). Software engineering: a practitioner's approach. Palgrave Macmillan.
5. Yamada, S. (2014). Software reliability modeling: fundamentals and applications. Tokyo: Springer.

Suggestive Readings: Nil

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