

# **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 & | Credits | Credit distribution of the course |          |            | Eligibility | Pre-requisite |
|----------------|---------|-----------------------------------|----------|------------|-------------|---------------|
| Code           |         | Lecture                           | Tutorial | Practical/ | criteria    | of the course |
|                |         |                                   |          | Practice   |             | (if any)      |
| Decision       | 4       | 3                                 | 1        | 0          |             | Nil           |
| Analysis and   |         |                                   |          |            |             |               |
| Game Theory    |         |                                   |          |            |             |               |
| (DSC - 19)     |         |                                   |          |            |             |               |

#### 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**

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

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**

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**

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

# 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
- 3. business (1st ed.). New York: Irwin (Richard D.) Inc.
- 4. Mastumoto, A., & Szidarovszky, F. (2016). Game theory and its applications. Springer.
- 5. 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.

# (10 hours)

(20 hours)

(12 hours)

(18 hours)

# **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**

| Course title & | Credits | Credit d | istribution | of the course | Eligibility | Pre-requisite |
|----------------|---------|----------|-------------|---------------|-------------|---------------|
| Code           |         | Lecture  | Tutorial    | Practical/    | criteria    | of the course |
|                |         |          |             | Practice      |             | (if any)      |
| Decision       | 4       | 3        | 1           | 0             |             | Nil           |
| Analysis and   |         |          |             |               |             |               |
| Game Theory    |         |          |             |               |             |               |
| (DSC - 13)     |         |          |             |               |             |               |

#### 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**

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

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**

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(**20 hours**)

#### (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**

#### (18 hours)

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

# 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 3. business (1st ed.). New York: Irwin (Richard D.) Inc.
- 4. Mastumoto, A., & Szidarovszky, F. (2016). *Game theory and its applications*. Springer.
- 5. 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)

|--|

| Course title &     | Credits | Credit d | istribution | of the course | Eligibility | Pre-requisite |
|--------------------|---------|----------|-------------|---------------|-------------|---------------|
| Code               |         | Lecture  | Tutorial    | Practical/    | criteria    | of the course |
|                    |         |          |             | Practice      |             | (if any)      |
| Decision           | 4       | 3        | 1           | 0             |             | Nil           |
| Analysis and       |         |          |             |               |             |               |
| Game Theory        |         |          |             |               |             |               |
| ( <b>DSC - 7</b> ) |         |          |             |               |             |               |

#### **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**

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

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**

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**

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

# 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
- 3. business (1st ed.). New York: Irwin (Richard D.) Inc.
- 4. Mastumoto, A., & Szidarovszky, F. (2016). Game theory and its applications. Springer.
- 5. 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.

#### (10 hours)

# (12 hours)

(20 hours)

# (18 hours)

# **Category IV**

# BSc. 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 – 7: Decision Analysis and Game Theory**

| Course title & | Credits | Credit distribution of the course |          |            | Eligibility | Pre-requisite |
|----------------|---------|-----------------------------------|----------|------------|-------------|---------------|
| Code           |         | Lecture                           | Tutorial | Practical/ | criteria    | of the course |
|                |         |                                   |          | Practice   |             | (if any)      |
| Decision       | 4       | 3                                 | 1        | 0          |             | Nil           |
| Analysis and   |         |                                   |          |            |             |               |
| Game Theory    |         |                                   |          |            |             |               |
| (DSC - 7)      |         |                                   |          |            |             |               |

#### 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**

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

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.

# (**10 hours**) of decision

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(20 hours)

#### **Unit III: Foundations of Game Theory**

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**

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

# Practical component (if any) - Nil Essential Readings:

- 6. Taha, H.A. (2007) Operations Research-An Introduction, 8th Edition, Prentice Hall.
- 7. Jones, J. M (1977). Introduction to decision theory, irwin series in quantitative analysis for
- 8. business (1st ed.). New York: Irwin (Richard D.) Inc.
- 9. Mastumoto, A., & Szidarovszky, F. (2016). Game theory and its applications. Springer.
- 10. 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 &      | Credits | Credit distribution of the course |          |            | Eligibility | <b>Pre-requisite</b> |
|---------------------|---------|-----------------------------------|----------|------------|-------------|----------------------|
| Code                |         | Lecture                           | Tutorial | Practical/ | criteria    | of the course        |
|                     |         |                                   |          | Practice   |             | (if any)             |
| Introduction        | 4       | 3                                 | 1        | 0          | -           | Nil                  |
| to Marketing        |         |                                   |          |            |             |                      |
| Research            |         |                                   |          |            |             |                      |
| ( <b>DSE-5</b> (a)) |         |                                   |          |            |             |                      |

#### (18 hours)

# (12 hours)

#### 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**

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**

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**

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**

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.

#### Practical component (if any) - Nil

#### **Essential Readings:**

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# (10 hours)

# (10 hours)

(20 hours)

#### (20 hours)

- 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 & | Credits | Credit distribution of the course |          |            | Eligibility | Pre-requisite |
|----------------|---------|-----------------------------------|----------|------------|-------------|---------------|
| Code           |         | Lecture                           | Tutorial | Practical/ | criteria    | of the course |
|                |         |                                   |          | Practice   |             | (if any)      |
| Advanced       | 4       | 3                                 | 1        | 0          | -           | Nil           |
| Inventory      |         |                                   |          |            |             |               |
| Management     |         |                                   |          |            |             |               |
| (DSE-5(b))     |         |                                   |          |            |             |               |

#### 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

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

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:

Aggregate planning, Master Production Schedule. Introduction to – Just in Time (JIT), Kanban system, and Vendor-Managed Inventory.

### Unit IV: Inventory control in Supply-Chains

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.

## 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. <u>Muckstadt</u>, J.A., & <u>Sapra, A.</u> (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*.2<sup>nd</sup> 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.

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# (16 hours)

(12 hours)

(16 hours)

(16 hours)

#### 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 &               | Credits | Credit d | istribution | of the course | Eligibility | Pre-requisite |
|------------------------------|---------|----------|-------------|---------------|-------------|---------------|
| Code                         |         | Lecture  | Tutorial    | Practical/    | criteria    | of the course |
|                              |         |          |             | Practice      |             | (if any)      |
| Portfolio                    | 4       | 3        | 1           | 0             | -           | Nil           |
| Management                   |         |          |             |               |             |               |
| ( <b>DSE-5</b> ( <b>c</b> )) |         |          |             |               |             |               |

#### 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 (15 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**

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**

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** (12 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.

#### 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.

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### (15 hours)

(18 hours)

#### **DISCIPLINE SPECIFIC ELECTIVE (DSE-5(d): STATISTICAL COMPUTING)**

#### CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course      | Credits | Credit di | stribution | of the course | Eligibility | Pre-requisite |
|-------------|---------|-----------|------------|---------------|-------------|---------------|
| title &     |         | Lecture   | Tutorial   | Practical/    | criteria    | of the course |
| Code        |         |           |            | Practice      |             | (if any)      |
| Statistical | 4       | 3         | 1          | 0             | -           | Nil           |
| Computing   |         |           |            |               |             |               |
| (DSE-5(d)   |         |           |            |               |             |               |

#### 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**

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**

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.

### (10 hours)

(10 hours)

### **Unit III: Bootstrap and Jackknife Methods**

(20 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**

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

# 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 & | Credits | Credit d | istribution | of the course | Eligibility | Pre-requisite |
|----------------|---------|----------|-------------|---------------|-------------|---------------|
| Code           |         | Lecture  | Tutorial    | Practical/    | criteria    | of the course |
|                |         |          |             | Practice      |             | (if any)      |
| Queueing       | 4       | 3        | 1           | 0             | -           | Nil           |
| Networks       |         |          |             |               |             |               |
| (DSE-5(e))     |         |          |             |               |             |               |

## **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:**

(**20 hours**)

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

Classification and basic concepts, Single class networks, Performance measures of queueing networks, Product-form networks.

#### **Unit II: Open queueing networks**

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**

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 Computer systems and communication systems, Service industry, Supply chain management.

#### 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) (2<sup>nd</sup> 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 (5<sup>th</sup> 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.

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(20 hours)

(10 hours)

(20 hours)

### (10 hours)

#### DISCIPLINE SPECIFIC ELECTIVE (DSE-5(f): RESEARCH METHODOLOGY)

# CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

| Course title & | Credits | Credit d | istribution | of the course | Eligibility | Pre-requisite |
|----------------|---------|----------|-------------|---------------|-------------|---------------|
| Code           |         | Lecture  | Tutorial    | Practical/    | criteria    | of the course |
|                |         |          |             | Practice      |             | (if any)      |
| Research       | 4       | 3        | 0           | 1             | -           | Nil           |
| Methodology    |         |          |             |               |             |               |
| (DSE-5(f))     |         |          |             |               |             |               |

#### **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**

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**

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**

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**

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.

# (6 hours)

(12 Hours)

(14 Hours)

# (13 Hours)

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#### Practical component (if any) –

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

#### **List of Practical:**

- Chi-square Test
- Mann Whitney U test.
- Wilcoxon Signed-Rank Test.
- One Way ANOVA
- Factor Analysis (PCA)
- 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 (7<sup>th</sup> 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 & | Credits | Credit d | istribution | of the course | Eligibility | Pre-requisite |
|----------------|---------|----------|-------------|---------------|-------------|---------------|
| Code           |         | Lecture  | Tutorial    | Practical/    | criteria    | of the course |
|                |         |          |             | Practice      |             | (if any)      |
| Quantitative   | 4       | 3        | 1           | 0             | -           | Nil           |
| Finance        |         |          |             |               |             |               |
| (GE-7(a))      |         |          |             |               |             |               |

#### 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 (18 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

(12 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

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 (14 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.

#### **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 & | Credits | Credit distribution of the course |          |            | Eligibility | Pre-requisite |
|----------------|---------|-----------------------------------|----------|------------|-------------|---------------|
| Code           |         | Lecture                           | Tutorial | Practical/ | criteria    | of the course |
|                |         |                                   |          | Practice   |             | (if any)      |
| Logistics and  | 4       | 3                                 | 1        | 0          | -           | Nil           |
| Supply Chain   |         |                                   |          |            |             |               |
| Management     |         |                                   |          |            |             |               |
| (GE-7(b))      |         |                                   |          |            |             |               |

(16 hours)

#### 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

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(15 Hours)Planning and inventory management, MRP, MRP-II, JIT, ERP, DRP, DRP-II, Facilitylocation, Customer relationship management, Role of IT in supply chain, Supply chain ITframework, Supply chain coordination, Bullwhip effect.

**Unit III: Procurement and Strategic Sourcing in Supply Chain Management (15 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

#### (15 Hours)

(15 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.

#### 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.