Goal Programming: Basics of goal programming, Weighted and pre-emptive goal programming, Formulation of a goal programming problem, Graphical solution method, Modified Simplex method.

Unit IV: Integer Linear Programming **(13 Hours)**

Introduction to Integer linear programming problem (ILPP), Pure ILPP, Mixed ILPP, and 0-1 ILPP, Formulation of real life ILPPs, Branch and bound solution method.

Practical component (if any) – NIL
Tutorial : [30 hours]

Essential/recommended readings

- Chandra, S., Jayadeva, & Mehra, A. (2013). *Numerical optimization with applications.* New Delhi: Narosa Publishing House.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).
- Taha , H.(2019). Operations Research-An Introduction, 10th edn., Pearson.
- Wayne, Winston, L. (2003). *Operations research: applications and algorithms,* (4th ed.). Duxbury Press.

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 CORE COURSE – 8: Statistical Inference

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 Inference (DSC-8)	4	3	0	1	-	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To acquaint the students with how to infer about the population using a sample drawn from it

- To explain how different parametric tests can be used in real life.

Learning outcomes

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

- Analyze the population or phenomenon from which the sample is drawn.
- Examine inferential methods wherein the distributional form of population or phenomenon from which the sample is drawn is known (parametric) .
- Conduct parametric tests of hypotheses

SYLLABUS OF DSC-8

Unit I: Introduction **(12 Hours)**
Concept of Inductive inference, Population and samples, Distribution of sample, statistic and sample moments, Sampling from Normal Distributions: Chi-Square, t and F-distributions, basic concepts of order statistics.

Unit II: Parametric Point Estimation **(12 Hours)**
Properties of point estimators- unbiasedness, consistency, sufficiency, efficiency, method of maximum likelihood for finding estimators, properties of maximum likelihood estimators, method of moments for finding estimators.

Unit III: Tests of Hypotheses **(12 Hours)**
Simple and Composite Hypotheses; Likelihood Ratio Tests; Construction of Confidence Intervals.

Unit IV: Parametric and Nonparametric Tests **(9 Hours)**
Normal tests for proportion and mean based on single sample ; Chi-Square test for variability; t-test for single mean; t-test for difference of means; paired t-test; F test for equality of variances, Chi-Square test for goodness of fit, sign test, Wilcoxon Signed Rank Test, Median Test.

Practical component (if any) [30 Hours] –

- Practicals based on applications of t-tests
- Practicals based on applications of F-tests
- Practicals based on applications of chi-square tests
- Practicals based on sign test, Wilcoxon Signed Rank Test,
- Practicals based on Median Test.

Essential/recommended readings

- Dudewicz, E. J., & Misra S. N. (1988). Modern mathematical statistics, Wiley.
- Fruend, J. E. (2013). Mathematical statistics with applications (8th ed.). Pearson Education India.
- Levin, R. I., Masood, H. S., Rubin, S. D., & Rastogi, S. (2017). Statistics for management (8th ed.). Pearson Education.

- Mood, A. M., Grabill, F. A., & Boes, D. C. (1974). Introduction to the theory of statistics (3rd ed.). McGraw Hill.

Suggestive readings:

- Goon, A. M., Gupta, A. K., & Dasgupta, B. (1989). An outline of statistical theory (volume 1) (2nd ed.). World Press Pvt. Ltd.
- Rohatgi, V. K., & Ehsanes Saleh, A. K. Md. (2000). An introduction to probability and statistics (2nd ed.). Wiley.

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

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 – 4: Optimization Techniques

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

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

Learning Objectives:
To impart knowledge about the formulations and solution techniques of integer linear and multi-objective goal programming problems.

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

- Identify different types of optimization problems and their characteristics in real life.
- Explain the theoretical concepts related to unconstrained optimization problems and demonstrate optimality conditions and solution approaches for them.
- Develop the concepts of a multi-objective programming problem and demonstrate its solution using goal programming.
- Formulate real-life problems as integer linear programming problems and solve them using Branch and Bound method.

SYLLABUS OF DSC-4

Unit I: Unconstrained Optimization **(10 Hours)**

Single and multiple variable problems, First and Second order necessary and sufficient conditions for finding extrema, Solution methods: Newton, Gradient search.

Unit II: **Convex Functions** **(10 Hours)**

Local and global maxima/minima for functions of one and two variables, inflection point, positive/negative definite and semi-definite matrices, convex/concave functions, and their properties, Verifying convexity/concavity through a Hessian matrix.

Unit III: Goal Programming **(12 Hours)**

Goal Programming: Basics of goal programming, Weighted and pre-emptive goal programming, Formulation of a goal programming problem, Graphical solution method, Modified Simplex method.

Unit IV: Integer Linear Programming (13 Hours)

Introduction to Integer linear programming problem (ILPP), Pure ILPP, Mixed ILPP, and 0-1 ILPP, Formulation of real life ILPPs, Branch and bound solution method.

Practical component (if any) – NIL
Tutorial: [30 Hours]

Essential/recommended readings

- Chandra, S., Jayadeva, & Mehra, A. (2013). *Numerical optimization with applications.* New Delhi: Narosa Publishing House.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).
- Taha , H.(2019). Operations Research-An Introduction, 10th edn., Pearson.
- Wayne, Winston, L. (2003). *Operations research: applications and algorithms,* (4th ed.). Duxbury Press.

Suggestive readings Nil

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

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 – 4: OPTIMIZATION TECHNIQUES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

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

Learning Objectives:
To impart knowledge about the formulations and solution techniques of integer linear and multi-objective goal programming problems.

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

- Identify different types of optimization problems and their characteristics in real life.
- Explain the theoretical concepts related to unconstrained optimization problems and demonstrate optimality conditions and solution approaches for them.
- Develop the concepts of a multi-objective programming problem and demonstrate its solution using goal programming.
- Formulate real-life problems as integer linear programming problems and solve them using Branch and Bound method.

SYLLABUS OF DSC-4

Unit I: Unconstrained Optimization **(10 Hours)**

Single and multiple variable problems, First and Second order necessary and sufficient conditions for finding extrema, Solution methods: Newton, Gradient search.

Unit II: Convex Functions **(10 Hours)**

Local and global maxima/minima for functions of one and two variables, inflection point, positive/negative definite and semi-definite matrices, convex/concave functions, and their properties, Verifying convexity/concavity through a Hessian matrix.

Unit III: Goal Programming **(12 Hours)**

Goal Programming: Basics of goal programming, Weighted and pre-emptive goal programming, Formulation of a goal programming problem, Graphical solution method, Modified Simplex method.

Unit IV: Integer Linear Programming **(13 Hours)**

Introduction to Integer linear programming problem (ILPP), Pure ILPP, Mixed ILPP, and 0-1 ILPP, Formulation of real life ILPPs, Branch and bound solution method.

Practical component (if any) – NIL
Tutorial:[30 Hours]

Essential/recommended readings

- Chandra, S., Jayadeva, & Mehra, A. (2013). *Numerical optimization with applications.* New Delhi: Narosa Publishing House.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).
- Taha , H.(2019). Operations Research-An Introduction, 10th edn., Pearson.
- Wayne, Winston, L. (2003). *Operations research: applications and algorithms,* (4th ed.). Duxbury Press.

Suggestive readings Nil

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

CATEGORY-V

COMMON POOL OF DISCIPLINE SPECIFIC ELECTIVES (DSE) COURSES OF

(i) B.Sc.(H) OR

(ii)B.Sc. (Physical Sciences/Mathematical Sciences) with OR as one of the

DISCIPLINE SPECIFIC ELECTIVE (DSE-2 (a)): Introduction to Stochastic Processes

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 Stochastic Processes (DSE-2(a))	4	3	1	0	-	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To acquaint students with the basic concepts of stochastic processes and its mathematical framework.
- To introduce some standard stochastic processes and their properties.
- To provide students necessary mathematical support and confidence to analyze the probabilistic evolution of randomly evolving systems.

Learning outcomes

Students completing this course will be able to:

- Elucidate the power of stochastic processes and their range of applications.
- State the defining properties of various stochastic process models.
- Demonstrate essential stochastic modeling tools.
- Identify appropriate stochastic process model(s) for a given research or applied problem.
- Formulate and solve problems which involve setting up stochastic models.

SYLLABUS OF DSE-2(a)

Unit I: Introduction to Stochastic processes **(6 hours)**

Definition, specification of stochastic processes, stationary processes, martingales.

Unit II: Markov chains **(12 hours)**

Introduction, Classification of states, Limiting behaviour, Applications to Queueing Theory.

Unit III: Markov Processes **(12 hours)**

Introduction, Structure of Markov Processes, Limit Theorems, Birth and Death Processes.

Unit IV: Counting Processes **(15 hours)**

Introduction, Types of counting processes, Poisson process: definition and examples, Markov property of Poisson process, superposition of Poisson processes, thinning of Poisson processes, basics of ordinary renewal processes and non-homogenous Poisson processes, Applications in Reliability and Maintenance Theory.

Practical component (if any) – NIL
Tutorial: [30 Hours]

Essential/recommended readings :

- Kulkarni, V. G. (2011), *Modeling and Analysis of Stochastic Systems*, (2nd edition), CRC Press.
- Ross, Sheldon, M. (1995). *Stochastic Processes* (2nd edition), John Wiley.
- Pinsky, Mark A. and Karlin, Samuel. (2011), *An Introduction to Stochastic Modeling*, Elsevier.
- Blanco, L., Arunachalam, V. and Dharmaraja S. (2016), *Introduction to Probability and Stochastic Processes with Applications,* Castaneda, Wiley, Asian Edition.

Suggestive readings:

- Medhi, J. (2009), *Stochastic Processes* (3rd edition), New Age International Publishers.
- Trivedi, K. S. (2016), *Probability & Statistics with Reliability, Queuing & Computer Science Applications* (2nd edition), New Jersey, John Wiley & Sons, Inc.

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

DISCIPLINE SPECIFIC ELECTIVE (DSE-2 (b)): Multivariate Data Analysis

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Multivariate Data Analysis & DSE 2(b)	4	3	0	**1**	Class XII with Mathematics	Knowledge of elementary descriptive and inferential Statistics

Learning Objectives

The primary objective of this course is to introduce:

- Understanding the principles and concepts of multivariate data analysis.
- Developing skills in using statistical software to analyze and interpret multivariate data.
- Familiarizing with different types of multivariate techniques.

Learning outcomes

Students completing this course will be able to:

- To examine the difference between univariate and multivariate data analysis.
- To analyse data using quantitative and qualitative response regression modelsregression models.
- To conduct factor analysis.

SYLLABUS OF DSE-2(b)

Unit I: Exploring Multivariate Data **(6 Hours)**

The aims of multivariate analysis, basics of matrix and vector algebra, positive definite matrices, random vectors, and matrices, mean vectors and covariance matrices, Types of Data; Organization of data- Arrays, Descriptive Statistics, Graphical Techniques- The scatterplot, The scatterplot matrix, multiple box plots, concept of distance in multivariate techniques, checking distributional assumptions using probability plots.

Unit II: Regression and the Analysis of variance **(15 Hours)**

Multiple Regression Models: Assumptions, Estimation, Testing of Hypotheses, ANOVA models, MANOVA(one-way classification)

Unit III: Qualitative Response Regression Models: **(12 Hours)**

Introduction, Binary Logistic Regression, Estimation, Goodness of fit, ROC curves, basics of multinomial logistic regression, use of logistic regression for classification, 2 x 2 contingency and three - way table.

Unit IV: Factor analysis **(12 Hours)**

Introduction, Exploratory factor analysis, reliability of factor scales: internal consistency of scales, Confirmatory factor analysis, Structural equation modelling.

Practical Component (if any) [30 Hours]:

- Practical based on multiple regression
- Practical based on ANOVA & MANOVA – one way classification
- Practical based on ANOVA – two way classification
- Practical based on Logistic Regression
- Practical based on Factor Analysis

Essential/recommended readings:

- Cleff, T. (2019). Applied Statistics and Multivariate Data Analysis for Business and Economics- A Modern Approach Using SPSS, Stata, and Excel, Springer Nature, Switzerland.

- Hardle, W. K. and Simar, L. (2015). Applied Multivariate Statistical Analysis, 4th Edn., Springer.

- Johnson, R. A. and Wichern, D. W. (2015). Applied Multivariate Statistical Analysis, 6th Edn., Pearson Education India.

- Joseph F. Hair Jr., Black,W.C., Babin,B.J., and Anderson, R.E. (2019). Multivariate Data Analysis, 8th edition, Cengage Learning, UK.

- Kshirsagar, A. M. (1996). Multivariate Analysis, 2nd ed., Marcel Dekker.

Suggestive Readings:Nil

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

SEMESTER-V

Category I

(B.Sc. Honours in Operational Research)

DISCIPLINE SPECIFIC CORE COURSE – 13: NONLINEAR AND DYNAMIC PROGRAMMING (THEORY AND PRACTICAL)

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		
Nonlinear and Dynamic Programming (DSC-13)	4	3	1	0	-	Nil

Learning Objectives:

- To impart knowledge about the formulations and solution techniques of nonlinear and dynamic programming.

Learning Outcomes:

Students completing this course will be able to:

- Identify different optimization problems and their characteristics in real-life to be formulated as nonlinear programming problems.
- Explain the theoretical concepts of nonlinear programming problems and demonstrate solution approaches.
- Understand the basics of Quadratic programming problems and describe their various applications. Then, demonstrate solution methods for these problems.
- Formulate and solve nonlinear programming problems in which the objective function and constraints are separable functions using concepts of separable programming.
- Solve different types of real-life problems using Dynamic programming.

SYLLABUS OF DSC-13

Unit I: **Nonlinear Programming (NLP)** **(15 Hours)**

Basics of NLP, Method of Lagrange multiplier, Fritz John optimality conditions, Karush-Kuhn-Tucker (KKT) optimality conditions, Verification of sufficient optimality conditions.

Unit II: Special Nonlinear Programming Problems **(15 Hours)**

Basics of Quadratic programming problem (QPP), Applications of QPP, Wolfe's method, Beale's method, Duality**,** Separable programming problem and its solution using piece-wise linear approximation.

Unit III: **Dynamic programming** **(15 Hours)**

Multistage decision processes, Recursive nature of computations, Forward and backward recursion, Bellman's principle of optimality, Selective dynamic programming applications and their solutions involving additive and multiplicative separable returns for objective as well as constraint functions, Problem of dimensionality.

Practical component (if any) – NIL
Tutorial: [30 Hours]

Essential/recommended readings

- Chandra, S., Jayadeva, & Mehra, A. (2013). *Numerical optimization with applications.* New Delhi: Narosa Publishing House.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).
- Sinha, S. M. (2006). *Mathematical programming- theory and methods* (1st ed.). New Delhi: Elsevier Science (Indian print).
- Wayne, Winston, L. (2003). *Operations research: applications and algorithms,* (4th ed.). Duxbury Press.

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 CORE COURSE – 14: Reliability 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		
Reliability Theory (DSC-14)	4	3	0	1	-	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To introduce students about the key concepts and methods in reliability engineering.

- To explain reliability modelling of systems with different configurations
- To explain concept of repair and its impact on the performance of the system along with formulation of maintenance and replacement policies

Learning outcomes

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

- To develop reliability models for non-repairable systems with different configurations
- Develop models for repairable systems using renewal process , Non Homogenous Poisson Process and State- space method
- Formulate system maintenance strategies.

SYLLABUS OF DSC-14

Unit I: Introduction (12 Hours)
Basics of reliability, Classes of life distributions based on notion of aging, concepts of structure function, coherent systems, cut sets, path sets, reliability of series, parallel, k-out-of-n, series-parallel, parallel-series, bridge structure, standby systems

Unit II: Repairable Systems (15 Hours)
Types of Repair, Availability theory, types of Availability measures, Perfect Repair Models: Introduction to Renewal theory, Types of Renewal Processes and their Asymptotic Properties, Reward Renewal Processes, Minimal Repair Models: Introduction to Non Homogenous Poisson Process, Power Law Process

Unit III: State Space Models for System Performance Analysis (10 Hours)
Markovian approach for reliability/ availability analysis of repairable series and parallel systems.

Unit IV: Maintenance Policies (8 Hours)
Types of Maintenance: Corrective Maintenance; Preventive Maintenance, Age Replacement Policy: cost type criterion, Block Replacement Policy: Cost-type criterion

Practical component (if any) [30 Hours]–

- Practicals based on computation of reliability of systems with various configurations
- Practicals based on finding reliability and availability measures of repairable series and parallel systems
- Practicals based on formulation of age and block replacement policies

Essential/recommended readings

- Barlow, R. E., & Proschan, F. (1975). Statistical theory of reliability and life testing. Holt, Rinehert & Winston Inc.
- Gertsbakh, I. (2013). Reliability theory with applications to preventive maintenance. Springer.
- Nakagawa, T. (2005). Maintenance theory on reliability. London: Springer-Verlag.

- Rau, J. G. (1970). Optimization and probability in systems engineering. V.N. Reinhold Co.
- Rausand, M., & Hoyland, A. (2003). System reliability theory: models, statistical methods, and applications. John Wiley & Sons.

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 CORE COURSE – 15: 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 (DSC-15)	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 DSC-15

Unit I: Introduction to finance functions (6 hours)

Purpose and objectives of Quantitative finance, financial markets, Functions of finance: Investment, Financing and Dividend decisions, roles and responsibilities of a finance manager.

Unit II: Time value of money **(9 hours)**

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 III: 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 IV: Financial statement analysis **(12 hours)**

Financial statements: Balance sheet, Income statement, Cash flows statement. Analysis of financial statements: Ratio analysis, Du Pont equations.

Unit V: Capital Budgeting and Working Capital Management **(9 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

Tutorial: [30 Hours]

Essential/recommended readings

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

Suggestive readings

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

Suggestive 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 – 9: Quantitative Finance and Marketing

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 and Marketing (DSC-9)	4	3	1	0	-	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To make students understand the basics of Financial Management.
- To impart knowledge of central concepts and methods of marketing and related optimization problems.
- To familiarize them with the principles, practices, techniques and applications of financial management, 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 and other management solutions.

SYLLABUS OF DSC- 9

Unit I: Introductory concepts in Quantitative finance **(9 Hours)**

Meaning, significance and scope of finance, profit maximization versus wealth maximization, Interpretation of finance function: Investment, financing and dividend decisions, Time value of money: Present Value and Future Value, Valuation of bonds, Risk and return: Capital Asset Pricing Model, Financial statements: Balance sheet, Income statement and Cash flows statement.

Unit II: Capital Budgeting and Working Capital Management (12 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.

Unit III: Market Analysis (12 Hours)

Concept of Marketing, Marketing Orientation and related concepts, Decision Making: A Quantitative Approach: Business Decisions, Abstraction, Model Building, Solutions, Errors, Model-Building Techniques, Marketing Mix-The Traditional 4 Ps, Marketing Mix- The Modern Concept, Diffusion Modeling, Buyers and Adopters, Mathematical Models for Consumer Buying Behaviour.

Unit IV: New Product Development and Management (12 Hours)

Product Life Cycle (PLC), Product line, Product mix strategies, New product development, , Brand switching analysis, Types of Competition: Perfect and Imperfect., Promotional Efforts and related Models

Practical component (if any) - Nil

Tutorial : [30 Hours]

Essential/recommended readings

- Curtis, A. (2008). Marketing for engineers, scientists and technologists. John Wiley & Sons.
- Gitman, L. J., Juchau, R., & Flanagan, J. (2015). *Principles of managerial finance*. Pearson Higher Education AU.
- Koller, T., Dobbs, R., & Huyett, B. (2010). *Value: The four cornerstones of corporate finance*. John Wiley & Sons.
- Levy, H., & Sarnat, M. (1988). *Principles of financial management*. Prentice Hall.
- Lilien, G. L., Kotler, P., & Moorthy, K. S. (2003). Marketing models. Prentice-Hall of India.
- Ross, S. A., Westerfield, R., & Jaffe, J. F. (1999). *Corporate finance*. Irwin/McGraw-Hill.
- Van Horne, J. C., & Wachowicz, J. M. (2008). *Fundamentals of financial management* (13th ed.). Harlow: Prentice Hall Inc.

Suggestive readings

- Blyth, S. (2013). *An introduction to quantitative finance*. Oxford University Press.
- Kotler, P., & Keller, K. L. (2009). Marketing management. Prentice-Hall.
- Wilmott, P. (2013). *Paul Wilmott on quantitative finance*. John Wiley & Sons.

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 CORE COURSE – 10: Stochastic Modelling and Applications

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		
Stochastic Modelling and Applications (DSC-10)	**4**	**3**	**0**	**1**	**-**	**Nil**

Learning Objectives

The Learning Objectives of this course are as follows:

- To make the students familiar with the concept of stochastic modeling and its applications in the field of queueing theory, reliability theory and inventory management.
- To provide students a rigorous mathematical framework to develop mathematical models for different queueing systems.
- To introduce students with the concept of system reliability and make them learn to evaluate reliability of various system configurations.
- To make students learn how to model uncertainties in demand in inventory management problems.
- To provide students hands-on experience of analyzing queueing, reliability and inventory models through practical sessions using certain software.

Learning Outcomes

Students completing this course will be able to:

- Learn the concepts of stochastic processes, Markov processes, Markov chains and apply these mathematical models in real-life problems.
- Understand the concepts and mathematical theory related to queuing systems & system reliability required to understand, analyse and solve any real-world problem.
- Evaluate the performance metrics of any queuing system.
- Compute the system reliability of any type of system-configuration.
- Understand and develop stochastic inventory models.
- Make use of software for problem analysis.

Syllabus of DSC-10

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

Basics of random variables, Probability distributions and their moments, Some standard probability distributions: Binomial, Poisson, Normal, Exponential, Random (stochastic) processes, Lack of memory property of exponential distribution, Markov process, Pure-birth process, Pure-death process.

Unit II: Introduction to Queueing Systems **(12 Hours)**

Characteristics of a queueing system, Kendall's notation, Performance measures of a queueing system, Markovian queueing models with single & multiple servers, and finite & infinite system capacity – M/M/1, M/M/c.

Unit III: System Reliability **(12 Hours)**

Introduction to reliability, Reliability function and related concepts like hazard rate, mean time to failure (MTTF), and mean time before failure (MTBF), Classes of lifetime distributions, Hazard rate of exponential and Weibull distributions, Reliability of various system configurations- series, parallel, mixed configuration, k out of n system and stand-by systems.

Unit IV: Stochastic inventory models **(12 Hours)**

Introduction to stochastic inventory models, Single period probabilistic inventory models with discrete and continuous demand.

Practical component (if any) [30 Hours]:

Practical/Lab to be performed using OR/Statistical packages

- Finding measures of performance for deterministic queuing system.
- Finding measures of performance for M/M/1 queuing system with infinite capacity.
- Finding measures of performance for M/M/1 queuing system with finite capacity.
- Finding measures of performance for M/M/c queuing system with infinite capacity.
- Measuring reliability of different types of system configuration.
- Measuring reliability, hazard rate and MTSF of different types of system configuration.
- Finding optimal inventory policy for probabilistic inventory model with discrete demand.

- Finding optimal inventory policy for probabilistic inventory model with continuous demand.

Essential/recommended readings

- Gross, D., Shortle, J. F, Thompson J. M., & Harris, C. M. (2008), *Fundamentals of Queuing Theory* (4th edition), New Jersey, John Wiley & Sons, inc.
- Rausand, M. & Hoyland, A. (2003), *System Reliability Theory: Models, Statistical Methods & Applications* (2nd edition), New Jersey, John Wiley & Sons, Inc.
- Rau, John G. (1970), *Optimization and Probability in Systems Engineering,* New York, Van Nostrand Reinhold Inc., U.S.
- Ross, S.N. (2008), *Stochastic Processes* (2nd edition), Wiley India Pvt. Ltd.
- Water, D. (2008). *Inventory control and management.* (2nd Edition). John Wiley & Sons.

Suggestive readings

- Hadley, G. and Whitin, T. M. (1979), *Analysis of Inventory Systems*, D. B. Taraporevala and Sons, Published by arrangement with Prentice Hall Inc.

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 – 5: Stochastic Modelling and Applications

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		
Stochastic Modelling and Applications (DSC-5)	**4**	**3**	**0**	**1**	**-**	**Nil**

Learning Objectives

The Learning Objectives of this course are as follows:

- To make the students familiar with the concept of stochastic modeling and its applications in the field of queueing theory, reliability theory and inventory management.
- To provide students a rigorous mathematical framework to develop mathematical models for different queueing systems.
- To introduce students with the concept of system reliability and make them learn to evaluate reliability of various system configurations.
- To make students learn how to model uncertainties in demand in inventory management problems.
- To provide students hands-on experience of analyzing queueing, reliability and inventory models through practical sessions using certain software.

Learning Outcomes

Students completing this course will be able to:

- Learn the concepts of stochastic processes, Markov processes, Markov chains and apply these mathematical models in real-life problems.
- Understand the concepts and mathematical theory related to queuing systems & system reliability required to understand, analyse and solve any real-world problem.
- Evaluate the performance metrics of any queuing system.
- Compute the system reliability of any type of system-configuration.

- Understand and develop stochastic inventory models.
- Make use of software for problem analysis.

Syllabus of DSC-5

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

Basics of random variables, Probability distributions and their moments, Some standard probability distributions: Binomial, Poisson, Normal, Exponential, Random (stochastic) processes, Lack of memory property of exponential distribution, Markov process, Pure-birth process, Pure-death process.

Unit II: Introduction to Queueing Systems **(12 Hours)**

Characteristics of a queueing system, Kendall's notation, Performance measures of a queueing system, Markovian queueing models with single & multiple servers, and finite & infinite system capacity – M/M/1, M/M/c.

Unit III: System Reliability **(12 Hours)**

Introduction to reliability, Reliability function and related concepts like hazard rate, mean time to failure (MTTF), and mean time before failure (MTBF), Classes of lifetime distributions, Hazard rate of exponential and Weibull distributions, Reliability of various system configurations- series, parallel, mixed configuration, k out of n system and stand-by systems.

Unit IV: Stochastic inventory models **(12 Hours)**

Introduction to stochastic inventory models, Single period probabilistic inventory models with discrete and continuous demand.

Practical component (if any) [30 Hours]:

Practical/Lab to be performed using OR/Statistical packages

- Finding measures of performance for deterministic queuing system.
- Finding measures of performance for M/M/1 queuing system with infinite capacity.
- Finding measures of performance for M/M/1 queuing system with finite capacity.
- Finding measures of performance for M/M/c queuing system with infinite capacity.
- Measuring reliability of different types of system configuration.
- Measuring reliability, hazard rate and MTSF of different types of system configuration.
- Finding optimal inventory policy for probabilistic inventory model with discrete demand.
- Finding optimal inventory policy for probabilistic inventory model with continuous demand.

Essential/recommended readings

- Gross, D., Shortle, J. F, Thompson J. M., & Harris, C. M. (2008), *Fundamentals of Queuing Theory* (4th edition), New Jersey, John Wiley & Sons, inc.
- Rausand, M. & Hoyland, A. (2003), *System Reliability Theory: Models, Statistical Methods & Applications* (2nd edition), New Jersey, John Wiley & Sons, Inc.

- Rau, John G. (1970), *Optimization and Probability in Systems Engineering,* New York, Van Nostrand Reinhold Inc., U.S.
- Ross, S.N. (2008), *Stochastic Processes* (2nd edition), Wiley India Pvt. Ltd.
- Water, D. (2008). *Inventory control and management.* (2nd Edition). John Wiley & Sons.

Suggestive readings

- Hadley, G. and Whitin, T. M. (1979), *Analysis of Inventory Systems*, D. B. Taraporevala and Sons, Published by arrangement with Prentice Hall Inc.

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

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 – 5: STOCHASTIC MODELLING AND APPLICATIONS

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		
Stochastic Modelling and Applications (DSC-5)	4	3	0	1	-	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To make the students familiar with the concept of stochastic modeling and its applications in the field of queueing theory, reliability theory and inventory management.
- To provide students a rigorous mathematical framework to develop mathematical models for different queueing systems.
- To introduce students with the concept of system reliability and make them learn to evaluate reliability of various system configurations.
- To make students learn how to model uncertainties in demand in inventory management problems.
- To provide students hands-on experience of analyzing queueing, reliability and inventory models through practical sessions using certain software.

Learning Outcomes

Students completing this course will be able to:

- Learn the concepts of stochastic processes, Markov processes, Markov chains and apply these mathematical models in real-life problems.
- Understand the concepts and mathematical theory related to queuing systems & system reliability required to understand, analyse and solve any real-world problem.
- Evaluate the performance metrics of any queuing system.

- Compute the system reliability of any type of system-configuration.
- Understand and develop stochastic inventory models.
- Make use of software for problem analysis.

Syllabus of DSC-5

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

Basics of random variables, Probability distributions and their moments, Some standard probability distributions: Binomial, Poisson, Normal, Exponential, Random (stochastic) processes, Lack of memory property of exponential distribution, Markov process, Pure-birth process, Pure-death process.

Unit II: Introduction to Queueing Systems **(12 Hours)**

Characteristics of a queueing system, Kendall's notation, Performance measures of a queueing system, Markovian queueing models with single & multiple servers, and finite & infinite system capacity – M/M/1, M/M/c.

Unit III: System Reliability **(12 Hours)**

Introduction to reliability, Reliability function and related concepts like hazard rate, mean time to failure (MTTF), and mean time before failure (MTBF), Classes of lifetime distributions, Hazard rate of exponential and Weibull distributions, Reliability of various system configurations- series, parallel, mixed configuration, k out of n system and stand-by systems.

Unit IV: Stochastic inventory models **(12 Hours)**

Introduction to stochastic inventory models, Single period probabilistic inventory models with discrete and continuous demand.

Practical component (if any) [30 Hours]:

Practical/Lab to be performed using OR/Statistical packages

- Finding measures of performance for deterministic queuing system.
- Finding measures of performance for M/M/1 queuing system with infinite capacity.
- Finding measures of performance for M/M/1 queuing system with finite capacity.
- Finding measures of performance for M/M/c queuing system with infinite capacity.
- Measuring reliability of different types of system configuration.
- Measuring reliability, hazard rate and MTSF of different types of system configuration.
- Finding optimal inventory policy for probabilistic inventory model with discrete demand.
- Finding optimal inventory policy for probabilistic inventory model with continuous demand.

Essential/recommended readings

- Gross, D., Shortle, J. F, Thompson J. M., & Harris, C. M. (2008), *Fundamentals of Queuing Theory* (4th edition), New Jersey, John Wiley & Sons, inc.
- Rausand, M. & Hoyland, A. (2003), *System Reliability Theory: Models, Statistical Methods & Applications* (2nd edition), New Jersey, John Wiley & Sons, Inc.

- Rau, John G. (1970), *Optimization and Probability in Systems Engineering,* New York, Van Nostrand Reinhold Inc., U.S.
- Ross, S.N. (2008), *Stochastic Processes* (2nd edition), Wiley India Pvt. Ltd.
- Water, D. (2008). *Inventory control and management.* (2nd Edition). John Wiley & Sons.

Suggestive readings

- Hadley, G. and Whitin, T. M. (1979), *Analysis of Inventory Systems*, D. B. Taraporevala and Sons, Published by arrangement with Prentice Hall Inc.

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

CATEGORY-V

COMMON POOL OF DISCIPLINE SPECIFIC ELECTIVES (DSE) COURSES OF

(i) B.Sc.(H) OR

(ii) BA(P)with OR Major & Minor

(iii) B.Sc. (Physical Sciences/Mathematical Sciences) with OR as one of

DISCIPLINE SPECIFIC ELECTIVE (DSE-3 (a)): Software Engineering

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Software Engineering (DSE-3(a))	4	3	0	1	Class XII Pass with Mathematics as one of the papers in Class XII	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 DSE-3(a)

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)

Practical component (if any) [30 Hours]:

Practical/Lab to be performed using OR/Statistical packages

- Problems related to Process Model
- Problems related to Requirement Analysis
- Problems related to Design Engineering
- Problems related to Project Management
- Problems related to Project Effort Estimation
- Problems related to Project Risk Management
- Problems related to Software Testing
- Problems related to Software Quality Assurance
- Software Reliability Prediction using mathematical models

Essential/recommended readings

- Aggarwal, K. K., & Singh Y. (2005). Software engineering, New Age International.
- Bell, D. (2005). Software Engineering for students. Pearson Education.
- Jalote, P. (2012). An integrated approach to software engineering. Springer Science & Business Media.
- Pressman, R. S. (2005). Software engineering: a practitioner's approach. Palgrave Macmillan.
- 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.

DISCIPLINE SPECIFIC ELECTIVE (DSE-3 (b)): Managerial Economics

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

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

Learning Objectives

The Learning Objectives of this course are as follows:

- To make students understand the concepts and techniques used in Micro-economic theory necessary for evaluating business decisions.
- To explain the importance and application of tools of micro economic theory in managerial decision-making.

Learning Outcomes

Students completing this course will be able to:

- Understand the application of economics principles most relevant to managers.
- Develop an understanding of basic concepts and issues in Managerial Economics and their applications in managerial decisions.
- Identify different economic factors and their importance in managerial decision making.
- Understand, evaluate and forecast demand and production functions in economics.
- Design competitive strategies according to the market structure.

SYLLABUS OF DSE-3 (b)

Unit I: Fundamentals of Managerial Economics (6 hours)

Introduction, scope and significance of managerial economics, circular flow in an economy, roles and responsibilities of managerial economist, theory and objectives of the firm, Managerial economics: Microeconomics and Macroeconomics.

Unit II: Demand and Supply analysis (15 hours)

Demand theory and determinants of demand, Law of demand, theory of consumer behavior, Price elasticity of demand, factors affecting price elasticity of demand, Income elasticity of demand, Cross price elasticity of demand, Determinants of Supply, Law of supply, elasticity of supply, Concept, significance and methods of demand forecasting.

Unit III: Cost and Production analysis (15 hours)

Meaning and significance of production, factors of production and production function, Production functions in the short run and long run, Concept and significance of cost, determinants of cost, cost function, types of cost, Economies and diseconomies of scale.

Unit IV: Market structures and pricing (9 hours)

Perfect competition: features and pricing under perfect competition, Monopoly: features and pricing under monopoly, Monopolistic competition: features and pricing under monopolistic competition, Oligopoly: features and pricing under oligopoly.

Practical component (if any) : NIL
Practical/Lab to be performed using OR/Statistical packages
Tutorial : [30 Hours]

Essential/recommended readings

- Mankiw, N. G. (2020). *Principles of economics*. Cengage Learning.
- Peterson, H. C., & Jain, S.K., & Lewis, W.C. (2006). *Managerial Economics* (4/e). Pearson Education.
- Salvator, D., & Rastogi, S.K. (2016). *Managerial Economics: Principles and Worldwide Applications* (8th Ed.). Oxford University Press.
- Samuelson, P., & Nordhaus, W. (2010). *Economics* (19th Ed.). McGraw Hill.
- Thomas, C. R., & Maurice, S. C. (2020). *Managerial economics* (12th Ed.). 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-3 (c)): HEALTH SYSTEMS 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		
Health Systems Modelling (DSE-3(c))	4	3	1	0	-	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- This course aims at providing a useful tool to bridge the ongoing trends of the health care system with the operational research techniques and methods by tackling problems through the integration of quantitative methods and operational research methodology.
- Use of common spreadsheet software, data modelling applications will prove to be the catalysts used for the management of health care system in a more practical environment.

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Learning Outcomes

Students completing this course will be able to:

- Apply their analytical skills and acknowledge the techniques underlining the decisions about delivering the healthcare of supreme quality.
- Review and describe the key roles and responsibilities of health care managers.
- Understand, brainstorm, and implement the scope of health services and follow the footprints of the recent trend in healthcare.
- Create a connection between the people's expectations and what the health care industry has to offer in the clearest way.
- Work on reducing regularity, risks and implementing measures to improve people's health and safety.
- Promote ethics and social responsibility at all levels of health services and management.

SYLLABUS OF DSE-3 (c)

Unit I: Health Care Business Operations & Role of Quantitative Methods (6 Hours)

Health care operations management: role, functions and need, Factors driving increased health care cost, Financial distress in health care, Characteristics of health care services and its management, Implications of operations and logistics management, importance of quantitative methods in health care management.

Unit II: Decision Making in Health Care and Quality Improvement (12 Hours)
Decision making under uncertainty and risk, sensitivity analysis, clinical decision making and its implications for management, Quantitative analysis in strategic planning. Business process map and its improvement methodology, service improvement, six sigma.

Unit III: Facility Location and Layout (6 Hours)
Location methods: Factor rating and center of gravity methods, GIS in health care, product layout**.**

Unit IV: Process Flow Optimization and Resource Optimization (16 Hours)
Discrete Event Simulation Methodology, Queuing analytics, Capacity problems: outpatient clinic, ICU capacity, operating rooms, daily load levelling of elective procedures, scheduling and staffing problems. Forecasting Time series and Regression analysis: patients' volume forecasting. Resource allocation problems: patients service volume, clinical unit staffing, resident physician restricted work hours, patients discharged from ED.

Unit V: Material Management (5 Hours)
Customer service in material management, Laundry and Linen, Role of Inventory in healthcare, inventory planning and policies**.**

Practical component (if any): NIL
Tutorial:[30 Hours]
Essential/recommended readings

- Denton, B. T. (2013). Handbook of healthcare operations management. New York: Springer, 10(978-1), 9.
- Kolker, A. (2011). Healthcare management engineering: What does this fancy term really mean?: The use of operations management methodology for quantitative decision-making in healthcare settings. Springer Science & Business Media.
- Langabeer, J. R. (2008). Health care operations management: a quantitative approach to business and logistics. Jones & Bartlett Learning.
- Lewis, J. B., McGrath, R. J., & Seidel, L. F. (2009). Essentials of applied quantitative methods for health services managers. Jones & Bartlett Publishers.
- Ozcan, Y. A. (2017). Analytics and decision support in health care operations management. John Wiley & Sons.
- Ozcan, Y. A. (2009). Quantitative methods in health care management: techniques and applications (2nd ed.). California: John Wiley & Sons.

Suggestive readings Nil

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 ELECTIVES (GE-5): SCHEDULING TECHNIQUES

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Scheduling Techniques (GE-5)	4	3	0	1	Nil	Nil

Learning Objectives

- To acquaint students with various scheduling problems and their real-life applications.

Learning outcomes

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

- Gain an understanding of network analysis and related mathematical models.
- Use standard methodologies for solving network flow problems.
- Manage projects with deterministic and probabilistic activity times.
- Carry out time-cost trade-off analysis in a project.
- Understand the utility of some sequencing problems.

SYLLABUS OF GE-5

Unit I: Introduction to Network Analysis **(12 hours)**

Meaning and application of a network diagram, Construction of a network diagram, time estimates in network analysis, float and slack analysis, critical path analysis, Critical path method (CPM) for project management.

Unit II: Project Scheduling **(12 hours)**

Program Evaluation and Review Technique (PERT) for project management, three time estimates in PERT, Expected completion time and standard deviation of completion time in PERT, probability of project completion within scheduled time.

Unit III: Project Crashing **(12 hours)**

Project time crashing (time-cost trade off analysis): meaning and significance for project management, direct and indirect costs, finding optimal completion time of project by doing time-cost trade off analysis.

Unit IV: Theory of sequencing **(9 hours)**

Basic concepts: sequencing of jobs through machines; total elapsed time; idle time on a machine; Gantt chart, Flow shop problem, Johnsons' optimality rule, parallel processing.

Practical component (if any) [30 Hours]–

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

- Construct the network of a project with deterministic activity times.
- Finding different types of floats involved in a project network.
- Conduct time-cost trade off analysis in the context of a project network.
- Construct the network of a project with probabilistic activity times.
- Finding expected completion time and variance of completion time in PERT.
- Finding probability of completing the project within scheduled time in PERT.
- Flow shop problem: processing of n Jobs through 2 machines.
- Flow shop problem: processing of n Jobs through 3 machines.
- Flow shop problem: parallel processing.

Essential/recommended readings

- Elmaghraby, S. E. (1977). Activity networks: project planning and control by network models. John Wiley & Sons.
- Ford Jr, L. R., & Fulkerson, D. R. (2015). Flows in networks. Princeton University Press.
- Levy, F. K., & Wiest, J. D. (2016). Management guide to PERT/CPM; with GERT/PDM/DCPM and other networks. Prentice-Hall of India.
- Swarup, K., & Gupta, P. K., & Mohan, M. (2019). Operations Research (Introduction to Management Science). Sultan Chand and Sons.

Suggestive readings: **Nil**

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

Semester-VI

Category I

(B.Sc. Honours in Operational Research)

DISCIPLINE SPECIFIC CORE COURSE – 16: 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 (DSC-16)	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 DSC 16

Unit I: Introduction to Quality Management (8 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 (12 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.

Practical component (if any) – Nil
Tutorial: [30 Hours]

Essential Readings:

- Charantimath, P. M. (2011). *Total Quality Management.* Pearson Education India: India.
- Gupta, S. C., & Kapoor, V. K. (2009). *Fundamentals of applied statistics*. India: Sultan Chand & Sons.
- 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:

- 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.

DISCIPLINE SPECIFIC CORE COURSE – 17: Quantitative Models in Marketing

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 Models in Marketing (DSC-17)	4	3	1	0	-	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To impart knowledge of central concepts and methods of marketing and related optimization problems.
- To impart knowledge of mathematical models available in handling real life situations.
- Formulations of various real-world problems arising in science, engineering, and management.

Learning outcomes

Students completing this course will be able to:

- Understand the concepts related to aid management decision making.
- Analyse the difference between different analytical perspectives, management decision tools used in businesses
- Apply their learning by formulating real-world problems under different categories
- Describe the theoretical workings of the producer as well as consumer
- Describe the theoretical workings of the innovation diffusion process and do sales forecasting for new products

SYLLABUS OF DSC-17

Unit I: Scientific Marketing Analysis **(8 Hours)**

Concept of Marketing, Marketing Orientation and related concepts, Decision Making: A Quantitative Approach: Business Decisions, Abstraction, Model Building, Solutions, Errors, Model-Building Techniques, Marketing Mix-The Traditional 4 Ps, Marketing Mix- The Modern Concept.

Unit II: Models of Consumer Behaviour (9 Hours)
Consumer Behaviour, Consumer buying process models, What Influences Consumer Behaviour, Key Psychological Processes, The Buying Decision Process: The Five Stage Model, Other Theories of Consumer Decision Making, External-Internal Influence Diffusion Model, The Howard-Sheth model of Buying Behaviour

Unit III: Theory of Pricing (9 Hours)
Product Markets: Perfect competition, Monopoly, Monopolistic competition, Oligopoly; Equilibrium determination and pricing under different market structures.

Unit IV: New Product Development and Management (9 Hours)
Product Life Cycle (PLC), Product line, Product mix strategies, New product development, Brand, Brand name selection, Brand equity, Brand switching analysis

Unit V: Promotional Management (10 Hours)
Promotion Mix, Push vs. Pull Strategy, Promotional Objectives, Advertising- Meaning and Importance, Types, Media Decisions (Mathematical Model for Media Allocation), Optimal Allocation of Advertising expenditure, Sales Promotion – Purpose and Types, Sales Response to Advertising in Presence of Competition.

Practical component (if any) – Nil
Practical/Lab to be performed on a computer using OR/Statistical packages
Tutorial :[30 Hours]

Essential Readings:

- Hooley G. J., & Hassey, M. K., (1999). Quantitative methods in marketing. International Thomson Business Press.
- Curtis, A. (2008). Marketing for engineers, scientists and technologists. John Wiley & Sons.
- Kotler, P., & Keller, K. L. (2009). Marketing management. Prentice-Hall.
- Lilien, G. L., Kotler, P., & Moorthy, K. S. (2003). Marketing models. Prentice-Hall of India.

Suggested Readings:

- Armstrong, G., Adam, S., Denize, S., & Kotler, P. (2014). Principles of marketing. Australia: Pearson.
- Dowling, G. R., & Dowling, G. R. (2004). The art and science of marketing: marketing for marketing managers. USA: Oxford University Press.

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

DISCIPLINE SPECIFIC CORE COURSE – 18: MACHINE LEARNING

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		
Machine Learning (DSC-18)	**4**	**3**	**0**	**1**	**-**	**Nil**

Learning Objectives

The Learning Objectives of this course are as follows:

- This course will present foundations of Machine Learning algorithms, as well as their real-world applications.
- The course will cover two major learning approaches: supervised and unsupervised.

Learning outcomes

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

- Differentiate between supervised and unsupervised learning tasks.
- Normalize the data and perform outlier analysis.
- Execute various machine learning algorithms learnt in the course.
- Understand the concepts of regression, clustering and dimensionality reduction.

SYLLABUS OF DSC-18

Unit I: Introduction to Machine Learning (8 Hours)

Definition, History, Future and basic concepts of Machine Learning, Statistical learning vs machine learning, Key elements of Machine Learning, Supervised vs. Unsupervised Learning, Data measurement scales, Feature Engineering: normalizing data, missing value treatment, outliers. Creating graphs (bar/line/pie/boxplot/histogram, etc.), summarizing data, descriptive statistics, univariate analysis (distribution of data), bivariate analysis (cross tabs, distributions and relationships, graphical analysis), Splitting dataset into training and test set.

Unit II: Supervised Learning- I (12 Hours)

Linear Regression: Regression with one variable, multiple variables, over-fitting, regularization. Regression evaluation metrics. Logistic Regression, Discriminant Analysis,

Unit III: Supervised Learning- II (12 Hours)

k-nearest neighbor classifier, Naive Bayes classifier, Neural networks, Boosting, Support vector Machines, Decision trees, Bagging, Ensemble of Trees, Evaluating a Classification Model Performance, K-fold Cross-validation, ROC Curve

Unit IV: Unsupervised Learning (13 Hours)

Clustering: Approaches for clustering, distance metrics, K-means clustering, hierarchical clustering, and feature selection methods. Dimensionality reduction (Principal Component Analysis). Association Rules Analysis.

Practical component (if any) [30 Hours]–

Use Python for practical labs for Machine Learning.

List of Practicals:

- Normalizing Data by Min-Max scaling
- Split datasets into training and test sets and evaluate the decision models.
- Summarizing Data through graphs and descriptive analysis.
- Create Prediction Model for linear regression.
- Make Prediction Model for logistic regression.
- Make prediction models for Naïve Bayes Classifier
- Implement Decision Tree
- Implement SVM classification.
- Perform K-means clustering.
- Perform Principal Component analysis.

Essential Readings

- Alpaydin, E. (2020). Introduction to machine learning. MIT press.
- Brownlee, J. (2018). Statistical methods for machine learning: Discover how to transform data into knowledge with Python. Machine Learning Mastery.
- James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). An introduction to statistical learning (Vol. 112, p. 18). New York: springer.
- Raschka, S., & Mirjalili, V. (2019). Python machine learning: Machine learning and deep learning with Python, scikit-learn, and TensorFlow 2. Packt Publishing Ltd.
- Shalev-Shwartz, S., & Ben-David, S. (2014). Understanding machine learning: From theory to algorithms. Cambridge university press.

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 – 11: Project 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		
Project Management (DSC-11)	4	3	0	1	-	Nil

Learning Objectives

The objective of this course is to acquaint students with the fundamental concepts of project planning and management.

Learning outcomes

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

- Formulate, evaluate, monitor and control a project.
- Gain an understanding of tools and techniques for project management.
- Use network analysis techniques to solve problems related to project management.
- Manage projects with deterministic and probabilistic activity times.
- Carry out time-cost trade-off analysis in a project.
- Understand the utility of some real-life applications of project management problems.

SYLLABUS OF DSC-11

Unit I: Introduction **(6 hours)**

Meaning of a project, project classification, Lifecycle and phases of a project, Concept of project management, Objectives and significance of project management, Roles and responsibilities of a project manager, Tools and techniques of project management.

Unit II: Project Appraisal **(12 hours)**

Market feasibility analysis: Market and demand analysis, collection of primary and secondary information, demand forecasting. Technical feasibility analysis: Material input and manufacturing process, selection of locations, Technology selection. Financial feasibility

analysis: Project cost estimation and working capital requirements, sources of financing, financial risk analysis using payback period and net present value techniques.

Unit III: Project Scheduling and Network analysis (12 hours)
Steps involved in project scheduling, Meaning and application of a network diagram, Construction of a network diagram for a project, time estimates in network analysis, float and slack analysis, critical path analysis, Introduction to Critical path method (CPM) and Program Evaluation and Review Technique (PERT) for project management.

Unit IV: Project Time Crashing (9 hours)
Project time crashing (time-cost trade off analysis): meaning and significance for project management, direct and indirect costs, finding optimal completion time of project by doing time-cost trade off analysis.

Unit V: Project Monitoring, Control and termination: (6 hours)
Data collection and reporting for project evaluation, Social cost-benefit analysis and Abandonment analysis. Project Termination: types of terminations, project termination process.

Practical component (if any) [30 Hours]-

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

- Construction of a network.
- Construct the network of a project with deterministic activity times.
- Finding different types of floats involved in a project network.
- Conduct time-cost trade off analysis in the context of a project network.
- Construct the network of a project with probabilistic activity times.
- Finding expected completion time and variance of completion time in PERT.
- Finding probability of completing the project within scheduled time in PERT.

Essential/recommended readings

- Bazaraa, M. S., Jarvis, J. J., & Sherali, H. D. (2011). Linear programming and network flows. John Wiley & Sons.
- Bertsekas, D. (1998). Network optimization: continuous and discrete models (Vol. 8). Athena Scientific.
- Elmaghraby, S. E. (1977). Activity networks: project planning and control by network models. John Wiley & Sons.
- Kerzner, H. (2017). *Project management: a systems approach to planning, scheduling, and controlling*. John Wiley & Sons.
- Larson, E. W., & Gray, C. F. (2021). Project management: The managerial process. 8th edition. McGraw-Hill Education.
- Levy, F. K., & Wiest, J. D. (2016). Management guide to PERT/CPM; with GERT/PDM/DCPM and other networks. Prentice-Hall of India.

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 CORE COURSE – 12: 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 (DSC-12)	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 DSC 12-

Unit I: Introduction to Quality Management (8 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 (12 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.

Practical component (if any) – Nil

Tutorial: [30 Hours]

Essential Readings:

- Charantimath, P. M. (2011). *Total Quality Management.* Pearson Education India: India.
- Gupta, S. C., & Kapoor, V. K. (2009). *Fundamentals of applied statistics*. India: Sultan Chand & Sons.
- 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:

- 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.

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 – 6: Project 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		
Project Management (DSC-6)	4	3	0	1	-	Nil

Learning Objectives

The objective of this course is to acquaint students with the fundamental concepts of project planning and management.

Learning outcomes

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

- Formulate, evaluate, monitor and control a project.
- Gain an understanding of tools and techniques for project management.
- Use network analysis techniques to solve problems related to project management.
- Manage projects with deterministic and probabilistic activity times.
- Carry out time-cost trade-off analysis in a project.
- Understand the utility of some real-life applications of project management problems.

SYLLABUS OF DSC-6

Unit I: Introduction **(6 hours)**

Meaning of a project, project classification, Lifecycle and phases of a project, Concept of project management, Objectives and significance of project management, Roles and responsibilities of a project manager, Tools and techniques of project management.

Unit II: Project Appraisal **(12 hours)**

Market feasibility analysis: Market and demand analysis, collection of primary and secondary information, demand forecasting. Technical feasibility analysis: Material input and manufacturing process, selection of locations, Technology selection. Financial feasibility

analysis: Project cost estimation and working capital requirements, sources of financing, financial risk analysis using payback period and net present value techniques.

Unit III: Project Scheduling and Network analysis (12 hours)
Steps involved in project scheduling, Meaning and application of a network diagram, Construction of a network diagram for a project, time estimates in network analysis, float and slack analysis, critical path analysis, Introduction to Critical path method (CPM) and Program Evaluation and Review Technique (PERT) for project management.

Unit IV: Project Time Crashing (9 hours)
Project time crashing (time-cost trade off analysis): meaning and significance for project management, direct and indirect costs, finding optimal completion time of project by doing time-cost trade off analysis.

Unit V: Project Monitoring, Control and termination (6 hours)
Data collection and reporting for project evaluation, Social cost-benefit analysis and Abandonment analysis. Project Termination: types of terminations, project termination process.

Practical component (if any) [30 Hours] -
Practical/Lab to be performed on a computer using OR/Statistical packages

- Construction of a network.
- Construct the network of a project with deterministic activity times.
- Finding different types of floats involved in a project network.
- Conduct time-cost trade off analysis in the context of a project network.
- Construct the network of a project with probabilistic activity times.
- Finding expected completion time and variance of completion time in PERT.
- Finding probability of completing the project within scheduled time in PERT.

Essential/recommended readings

- Bazaraa, M. S., Jarvis, J. J., & Sherali, H. D. (2011). Linear programming and network flows. John Wiley & Sons.
- Bertsekas, D. (1998). Network optimization: continuous and discrete models (Vol. 8). Athena Scientific.
- Elmaghraby, S. E. (1977). Activity networks: project planning and control by network models. John Wiley & Sons.
- Kerzner, H. (2017). *Project management: a systems approach to planning, scheduling, and controlling*. John Wiley & Sons.
- Larson, E. W., & Gray, C. F. (2021). Project management: The managerial process. 8th edition. McGraw-Hill Education.
- Levy, F. K., & Wiest, J. D. (2016). Management guide to PERT/CPM; with GERT/PDM/DCPM and other networks. Prentice-Hall of India.

Suggestive readings: Nil

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

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 – 6 Project 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		
Project Management (DSC-6)	4	3	0	1	-	Nil

Learning Objectives

The objective of this course is to acquaint students with the fundamental concepts of project planning and management.

Learning outcomes

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

- Formulate, evaluate, monitor and control a project.
- Gain an understanding of tools and techniques for project management.
- Use network analysis techniques to solve problems related to project management.
- Manage projects with deterministic and probabilistic activity times.
- Carry out time-cost trade-off analysis in a project.
- Understand the utility of some real-life applications of project management problems.

SYLLABUS OF DSC-6

Unit I: Introduction **(6 hours)**

Meaning of a project, project classification, Lifecycle and phases of a project, Concept of project management, Objectives and significance of project management, Roles and responsibilities of a project manager, Tools and techniques of project management.

Unit II: Project Appraisal **(12 hours)**

Market feasibility analysis: Market and demand analysis, collection of primary and secondary information, demand forecasting. Technical feasibility analysis: Material input and manufacturing process, selection of locations, Technology selection. Financial feasibility

analysis: Project cost estimation and working capital requirements, sources of financing, financial risk analysis using payback period and net present value techniques.

Unit III: Project Scheduling and Network analysis (12 hours)
Steps involved in project scheduling, Meaning and application of a network diagram, Construction of a network diagram for a project, time estimates in network analysis, float and slack analysis, critical path analysis, Introduction to Critical path method (CPM) and Program Evaluation and Review Technique (PERT) for project management.

Unit IV: Project Time Crashing (9 hours)
Project time crashing (time-cost trade off analysis): meaning and significance for project management, direct and indirect costs, finding optimal completion time of project by doing time-cost trade off analysis.

Unit V: Project Monitoring, Control and termination (6 hours)
Data collection and reporting for project evaluation, Social cost-benefit analysis and Abandonment analysis. Project Termination: types of terminations, project termination process.

Practical component (if any) [30 Hours] -
Practical/Lab to be performed on a computer using OR/Statistical packages

- Construction of a network.
- Construct the network of a project with deterministic activity times.
- Finding different types of floats involved in a project network.
- Conduct time-cost trade off analysis in the context of a project network.
- Construct the network of a project with probabilistic activity times.
- Finding expected completion time and variance of completion time in PERT.
- Finding probability of completing the project within scheduled time in PERT.

Essential/recommended readings

- Bazaraa, M. S., Jarvis, J. J., & Sherali, H. D. (2011). Linear programming and network flows. John Wiley & Sons.
- Bertsekas, D. (1998). Network optimization: continuous and discrete models (Vol. 8). Athena Scientific.
- Elmaghraby, S. E. (1977). Activity networks: project planning and control by network models. John Wiley & Sons.
- Kerzner, H. (2017). *Project management: a systems approach to planning, scheduling, and controlling*. John Wiley & Sons.
- Larson, E. W., & Gray, C. F. (2021). Project management: The managerial process. 8th edition. McGraw-Hill Education.
- Levy, F. K., & Wiest, J. D. (2016). Management guide to PERT/CPM; with GERT/PDM/DCPM and other networks. Prentice-Hall of India.

Suggestive readings: Nil

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

CATEGORY-V

COMMON POOL OF DISCIPLINE SPECIFIC ELECTIVES (DSE) COURSES

(i)B.Sc. (H) OR

(ii)BA(P)with OR AS Major & Minor DISCIPLINE

(iii)B.Sc. (Physical Sciences/Mathematical Sciences) with OR as one of the

DISCIPLINE SPECIFIC ELECTIVE (DSE-4 (a)): Econometric 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		
Econometric Modelling (DSE-4(a))	4	3	0	1	-	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To explain the meaning of econometrics-the social science in which the tools of economic theory, mathematics and statistical inference are applied to study economic phenomena.
- To explain the need and concept behind single equation regression models – Single and Multiple Linear Regression Models and also underlying methodology
- To explain Time Series modelling and forecasting.
- To explain the purpose, concept and methodology behind simultaneous equation models.

Learning Outcomes

Students completing this course will be able to:

- Understand concepts, issues and applications of econometric modelling.
- Analyse Econometric model involving single equation with single response variable.
- Analyse Econometric model involving single equation with multiple response variables.
- Analyse time series and simultaneous equation models.

SYLLABUS OF DSE-4(a)

Unit I: Introduction to Econometrics (6 hours)
The nature and scope of Econometrics, The Methodology of Econometrics, Types of data: Time series data, Cross-sectional data, Panel data

Unit II: Regression Analysis (15 hours)
Classical Linear Regression Models (CLRMs): Single and Multiple linear regression, Model coefficients, Ordinary least squares estimation, Residuals, fitted values, goodness of fit, Violating the assumptions of CLRMs: Multicollinearity; Hetreoscedasticity; Autocorrelation, Step-wise regression.

Unit III: Time Series Modelling (12 hours)
Stationary and non-stationary time series, Consequences and detection of non-stationarity, Introduction to AR, MA and ARMA models, ARIMA model, Box Jenkins approach to forecasting.

Unit IV: Simultaneous Equations Modelling (12 hours)
Simultaneous equations models: Basic definitions, Identification problem, Estimation, Forecasting from a simultaneous model

Practical component (if any) [30 Hours]-

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

- Fitting of a single linear regression model using ordinary least squares estimation.
- Fitting of a multiple linear regression model having two explanatory variables using ordinary least squares estimation.
- Fitting of a multiple linear regression model having more than two explanatory variables using ordinary least squares estimation.
- Testing for the presence of Multicollinearity.
- Testing for the presence of Heteroscedasticity.
- Testing for the presence of Autocorrelation.
- Testing for stationary and non-stationary time series.
- Estimating a simultaneous equations model.
- Forecasting from a simultaneous equations model.

Essential/recommended readings

- Dougherty, C. (2011). Introduction to econometrics (4th ed.). New York: Oxford University Press.
- Gujarati , D.N., Porter, D.C., and Pal, M.(2020) Basic Econmerics , McGraw Hill Publications.
- Johnston, J. (1984). Econometric methods (3rd ed.). New York: Mc-Graw Hill.
- Koutsoyiannis, A. (2001). Theory of econometrics (2nd ed.). New York: Palgrave Macmillan.

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-4 (b)): 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 4(b)	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 DSC 4(b)

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.

Practical component (if any) [30 Hours] –
Use Microsoft Excel/SPSS for practical labs for Research Methodology

List of Practicals:
- Chi-square Test
- Mann Whitney U test.
- Wilcoxon Signed-Rank Test.
- One Way ANOVA
- Factor Analysis (PCA)
- Discriminant Analysis (LDA)

Essential/recommended readings

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

Suggestive readings:

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

DISCIPLINE SPECIFIC ELECTIVE (DSE-4 (c)): INDUSTRIAL PROJECT

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		
Industrial Project (DSE-4(c))	4	0	0	4	-	Nil

A Student will be required to do an industrial project

CATEGORY-VI

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

GENERIC ELECTIVES (GE-6): QUANTITATIVE MODELS IN MARKETING

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
		Lecture	Tutorial	Practical/ Practice		
Quantitative Models in Marketing (GE-6)	4	3	1	0	Nil	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To impart knowledge of central concepts and methods of marketing and related optimization problems.
- To impart knowledge of mathematical models available in handling real life situations.
- Formulations of various real-world problems arising in science, engineering, and management.

Learning outcomes

Students completing this course will be able to:

- Understand the concepts related to aid management decision making.
- Analyse the difference between different analytical perspectives, management decision tools used in businesses
- Apply their learning by formulating real-world problems under different categories
- Describe the theoretical workings of the producer as well as consumer
- Describe the theoretical workings of the innovation diffusion process and do sales forecasting for new products

SYLLABUS OF GE-6

Learning Objectives

The Learning Objectives of this course are as follows:

- To impart knowledge of central concepts and methods of marketing and related optimization problems.
- To impart knowledge of mathematical models available in handling real life situations.
- Formulations of various real-world problems arising in science, engineering, and management.

Learning outcomes

Students completing this course will be able to:

- Understand the concepts related to aid management decision making.
- Analyse the difference between different analytical perspectives, management decision tools used in businesses
- Apply their learning by formulating real-world problems under different categories
- Describe the theoretical workings of the producer as well as consumer
- Describe the theoretical workings of the innovation diffusion process and do sales forecasting for new products

SYLLABUS OF GE-6

Unit I: Scientific Marketing Analysis (8 Hours)
Concept of Marketing, Marketing Orientation and related concepts, Decision Making: A Quantitative Approach: Business Decisions, Abstraction, Model Building, Solutions, Errors, Model-Building Techniques, Marketing Mix-The Traditional 4 Ps, Marketing Mix- The Modern Concept.

Unit II: Models of Consumer Behaviour (9 Hours)
Consumer Behaviour, Consumer buying process models, What Influences Consumer Behaviour, Key Psychological Processes, The Buying Decision Process: The Five Stage Model, Other Theories of Consumer Decision Making, External-Internal Influence Diffusion Model, The Howard-Sheth model of Buying Behaviour

Unit III: Theory of Pricing (9 Hours)
Product Markets: Perfect competition, Monopoly, Monopolistic competition, Oligopoly; Equilibrium determination and pricing under different market structures.

Unit IV: New Product Development and Management (9 Hours)
Product Life Cycle (PLC), Product line, Product mix strategies, New product development, Brand, Brand name selection, Brand equity, Brand switching analysis

Unit V: Promotional Management (10 Hours)
Promotion Mix, Push vs. Pull Strategy, Promotional Objectives, Advertising- Meaning and Importance, Types, Media Decisions (Mathematical Model for Media Allocation), Optimal Allocation of Advertising expenditure, Sales Promotion – Purpose and Types, Sales Response to Advertising in Presence of Competition.

Practical component (if any) – NA

Practical/Lab to be performed on a computer using OR/Statistical packages
Tutorial: [30 Hours]
Essential Readings:

- Hooley G. J., & Hassey, M. K., (1999). Quantitative methods in marketing. International Thomson Business Press.
- Curtis, A. (2008). Marketing for engineers, scientists and technologists. John Wiley & Sons.
- Kotler, P., & Keller, K. L. (2009). Marketing management. Prentice-Hall.
- Lilien, G. L., Kotler, P., & Moorthy, K. S. (2003). Marketing models. Prentice-Hall of India.

Suggested Readings:

- Armstrong, G., Adam, S., Denize, S., & Kotler, P. (2014). Principles of marketing. Australia: Pearson.
- Dowling, G. R., & Dowling, G. R. (2004). The art and science of marketing: marketing for marketing managers. USA: Oxford University Press.

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