INDIAN STATISTICAL INSTITUTE

Students' Brochure
PART II

Master of Technology in Quality, Reliability and Operations Research

(Effective from 2026-27 Academic Year)

(See PART I for general information, rules and regulations)

The Headquarters is at
203 BARRACKPORE TRUNK ROAD
KOLKATA 700108

INDIAN STATISTICAL INSTITUTE

Master of Technology in Quality, Reliability and Operations Research

Contents

SUBJECTS (COURSES) FOR INSTRUCTION AND GRADES

1 Curriculum

The first year of this two-year programme is divided into streams, for students from Engineering background (E-stream) and those from Statistics background (S-stream). The two streams merge in the second year. Altogether there are 15 courses, including 2 elective courses in the third semester. Each of these courses is allocated for about four lecture hours per week. There is a summer internship in between the first and the second years (i.e., between the second and third semesters). The fourth semester consists of a dissertation or industrial project work at the locations of internship.

First Year: Engineering Stream

Semester I (500 marks)	Semester II (500 marks)
Probability	Stochastic Processes
Statistical Methods I	Statistical Methods II
Operations Research I	Regression and Time series Analyses
Programming Techniques and Data Structures	Reliability I
Quality Management	Industrial Engineering and Supply Chain Management

First Year: Statistics Stream

Semester I (500 marks)	Semester II (500 marks)
Electrical and Electronics Engineering	Mechanical Engineering
Engineering Drawing and Workshop I	Workshop II
Operations Research I	Regression and Time series Analyses
Programming Techniques and Data Structures	Reliability I
Quality Management	Industrial Engineering and Supply Chain Management

Note:

Duration: First Year, Semester-I: 16 weeks (14 weeks of class): July to December
First Year, Semester-II: 16 weeks (14 weeks of class): January to May*

*** A 10-week Summer Internship starts immediately after Semester II examination.**

Second Year: Engineering & Statistics Streams

Semester I (500 marks)	Semester II (500 marks)
Operations Research II	Summer Internship*
Reliability II	Dissertation or Industry Project
Statistical Quality Control	
Elective I	
Elective II	

*100 marks of Summer Internship are carried forward to the Second Year, Semester II.

Elective Courses **

- Machine Learning
- Business Analytics
- Database Management Systems
- Quantitative Finance
- Industrial Experimentation
- Applied Multivariate Analysis
- Six Sigma

**The elective subjects to be offered will be decided based on the availability of the concerned teachers. Any two elective courses will have to be chosen by the students as credit courses from the list of electives being offered. Also, the students may choose at the most one more elective course as non-credit course.

Note:

Duration: Second Year, Semester-I: 16 weeks (14 weeks of class): July to December
Second Year, Semester-II: Dissertation / Industry Project: January to June

2 Detailed Syllabi of Courses

The number shown in parentheses after a particular topic indicates the suggested number of lectures allocated to that topic.

2.1 First Semester Courses

PROBABILITY (50)

Concept of Probability (10)

Introduction and citation of examples for applications of probability. Concept of random experiment with examples. Sample space and events. Classical definition of probability and its drawbacks. Axiomatic definition of probability. Discrete and general probability space. Properties of probability. Combinatorial probability. Conditional probability, Bayes' theorem. Independence of events, pair wise and mutual independence.

Concept of Random Variables and Probability Distributions (10)

Definition of random variable, Discrete random variables and their pmf and cdf. Continuous random variables and their pdf and cdf.

Mathematical expectation and variance, and their properties; mgf, pgf and cf – definitions, properties and relationship. Statement of uniqueness theorem of cf and its applications. Moments, their properties and interpretation. Moments through pgf, mgf and cf. Variance of sum of independent random variables. Conditional expectation. Conditional variance.

Discrete Random Variable and its Distribution (8)

Binomial, Poisson, geometric, negative binomial, hypergeometric distributions: properties, relationship and simple approximations (Hypergeometric to binomial and binomial to Poisson). Numerical examples. Statistical tables for individual and cumulative probabilities. Marginal and conditional density functions, independence of discrete random variables. Distribution of the sum of two or more discrete independent random variables.

Continuous Random Variable and its Distribution (8)

Uniform, normal, gamma, beta, exponential, Weibull, Cauchy, lognormal distributions. Relationship between gamma and Poisson, beta and binomial distributions. Independence of continuous random variables. Distribution of sum, product and ratio of two independent random variables. Some derived distributions such as χ^2, t and F distributions. Order statistics and distribution of range.

Bivariate Distribution (8)

Bivariate distribution - marginal and conditional density. Bivariate normal distribution. Correlation coefficient and its properties. Extension to multivariate normal distribution.

Limit Theorems (6)

Chebyshev's lemma, Chebyshev's inequality, Weak law of large numbers (WLLN), Central limit theorem (Lindbergh & Levy). De Moivre's theorem; examples of application of these limit theorems in Statistical Quality Control.

References

1. S.M. Ross.Introduction of Probability Models, Academic Press, New York.
2. S.M. Ross. A First Course in Probability,9th Ed., Pearson Education Limited.
3. P.G. Hoel, S.C. Port and C.J. Stone.Introduction to Probability Theory. Houghton Mifflin, Boston.
4. R. P. Dobrow.Probability with Applications and R, John Wiley & Sons, Hoboken, New Jersy.
5. M. Fisz. Probability Theory and Mathematical Statistics, Wiley, London.
6. M. Mood, F.A.Graybill, D.C. Boes. Introduction to the Theory of Statistics, McGraw Hill, New York.
7. V. K. Rohatgi and A. K. Md. E. Saleh.An Introduction to Probability and Statistics, John Wiley and Sons, New York.
8. J. E. Freund.Mathematical Statistics, Prentice Hall of India.
9. E. J. Dudewicz and S. N. Mishra.Modern Mathematical Statistics, Wiley.
10. H. Cramér. Mathematical Methods of Statistics, Princeton University Press.
11. K. L. Chung. Elementary Probability Theory with Stochastic Processes, Springer Verlag, New York.
12. M. Gun, M. K. Gupta and B. Dasgupta. An Outline of Statistical Theory: Volume I, World Press.

STATISTICAL METHODS – I (50)

Introduction (4)

Definition of Statistics: scope, purpose, and objectives. Population and sample. Measurement scales. Types of data. Primary and secondary data.

Descriptive Statistics (20)

Classification and tabulation of univariate data. Data visualization techniques – line diagram, bar diagram, pie chart etc. Frequency distribution and histogram - cumulative frequency curve. Descriptive measures of central tendency and dispersion, quantiles, skewness and kurtosis. Box plot. Bivariate data -summarization. Marginal and conditional frequency distribution, scatter diagram, correlation coefficient, simple linear regression, rank correlation and correlation ratio. Contingency table, measures of association.

Sampling Techniques (8)

Random number. Sampling frame. Random sampling from finite and infinite populations. Simple random sampling (with replacement and without replacement). Expectation and standard error of sample mean and sample proportion. Introduction to other sampling techniques - Stratified, systematic and cluster.

Estimation (10)

Principles of statistical inference. Formulation of problems with examples. Point estimation. Estimator and estimate. Criteria for good estimates - unbiasedness, consistency, efficiency and sufficiency. Method of moments estimation, Maximum likelihood estimation. Fisher Information matrix. Properties of maximum likelihood estimator. Confidence intervals.

Distribution Fitting (4)

Empirical distribution function, Kernel density estimation, Fitting of univariate distribution by graphical method (PP and QQ plots).

Simulation (4)

Simulation of probability distributions (univariate and bivariate).

Illustrations with specific examples and numerical exercises using statistical packages `R/Python`.

References

1. D. C. Montgomery and G. C. Runger, *Applied Statistics and Probability for Engineers*, John Wiley & Sons.
2. H. Lee, *Foundations of Applied Statistical Methods*, Springer.
3. G. K. Bhattacharya and R. A. Johnson, *Statistical Concepts & Methods*, Wiley.
4. D. Freedman, R. Pisani, and R. Purves, *Statistics*, Viva Books.
5. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, Wiley.
6. W. M. Mendenhall and T. L. Sincich, *Statistics for Engineering and the Sciences*, CRC Press.
7. A. M. Gun, M. K. Gupta, and B. Dasgupta, *Fundamentals of Statistics, Volume I*, World Press.
8. M. Gun, M. K. Gupta, and B. Dasgupta, *An Outline of Statistical Theory, Volume I*, World Press.

OPERATIONS RESEARCH – I (50)

Introduction to Operations Research (OR) (2)

Origin of OR and its definition, concept of optimizing performance measures, types of OR problems, deterministic vs. stochastic optimization, phases of OR problems approach - problem formulation, building mathematical model, deriving solutions, validating model, controlling and implementing solution.

Overview of Linear Algebra (2)

System of linear equations, concept of vector spaces and subspaces, dimension and basis, linear transformation, matrices, eigen value and eigen vector, inner product.

Overview of Real Analysis (2)

Real number system, elements of point set theory, sequences and series, concept of limit, continuity, derivative and Riemann integration.

Linear Programming Problem (LPP) (17)

Linear programming – examples from industrial cases, formulation and definitions of LPP and its matrix form, implicit assumptions of LPP, hyperplane, convex set, extreme points, basic feasible solution.

Geometric method -two-variable case, special cases - infeasibility, unboundedness, redundancy and degeneracy. Sensitivity analysis.

Simplex algorithm – slack, surplus and artificial variables, computational details, big-M method, two-phase method, identification and resolution of special cases through simplex iterations.

Duality - formulation, results, fundamental theorem of duality, dual-simplex algorithms.

Transportation Problem (TP) and Assignment Problem (AP) (6)

TP -examples, definitions - decision variables, supply and demand constraints, formulation, balanced and unbalanced situations, solution methods - NWCR, minimum cost and VAM, test for optimality (MODI method), degeneracy and its resolution, transhipment problems and solutions.

AP -examples, definitions - decision variables, constraints, formulation, balanced and unbalanced situations, solution method - Hungarian method, test for optimality (MODI method), degeneracy and its resolution.

Project Management (3)

Project definition, project scheduling techniques - Gantt chart, PERT and CPM, determination of critical paths, estimation of project time and its variance in PERT using statistical principles, concept of project crashing/time-cost trade off.

Inventory Management (8)

Functions of inventory and its disadvantages, ABC analysis, concept of inventory costs, basics of inventory policy (order, lead time, types), fixed order-quantity models - EOQ, POQ and quantity discount models, EOQ models for discrete units, sensitivity analysis and robustness, special cases of EOQ models for safety stock with known/unknown stock out situations, models under prescribed policy, probabilistic situations.

Queuing Theory (6)

Definitions - queue (waiting line), waiting costs, characteristics (arrival, queue, service discipline) of queuing system, queue types (channel vs. phase).

Kendall's notation, Little's law, steady state behaviour, Possion's process and queue, models with examples - M/M/1 and its performance measures; M/M/m and its performance measures; brief about some special models.

Simulation Methodology (4)

Definition and steps of simulation, random number, random number generator, discrete event system simulation - clock, event list, application in scheduling, queuing systems, inventory systems.

References

1. K. Hoffman and R. Kunze, *Linear Algebra*, Prentice-Hall, New Jersey.
2. A. R. Rao and P. Bhimsankaram, *Linear Algebra*, Springer.
3. T. M. Apostol, *Mathematical Analysis*, Addison-Wesley.
4. F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research*, Addison-Wesley.
5. H. A. Taha, *Operations Research: An Introduction*, Macmillan, New York.
6. A. R. Ravindran, *Operations Research and Management Science Handbook*, CRC Press.
7. G. Hadley, *Linear Programming*, Addison-Wesley.
8. M. S. Bazaraa, J. J. Jarvis, and H. D. Sherali, *Linear Programming and Network Flows*, John Wiley.

9. G. Dantzig, *Linear Programming and Extensions*, Princeton University Press.

10. J. P. Lewis, *Fundamentals of Project Management*, AMA.

11. J. D. Wiest and F. K. Levy, *A Management Guide to PERT/CPM*, PHI.

12. N. Singh, *Project Management and Control*, Himalaya Publishing House.

13. J. R. Meredith and S. J. Mantel, *Project Management: A Managerial Approach*, John Wiley.

14. H. Kerzner, *Project Management: A Systems Approach*, John Wiley.

15. J. W. Prichard and R. H. Eagle, *Modern Inventory Management*, John Wiley.

16. M. K. Starr and R. J. Tersine, *Materials Management in Inventory Systems*, North Holland.

17. D. R. Cox and W. L. Smith, *Queues*, CRC Press.

18. J. A. White, J. W. Schmidt, and G. K. Bennett, *Analysis of Queuing Systems*, Academic Press.

19. T. L. Saaty, *Elements of Queuing Theory*, McGraw-Hill.

20. N. U. Prabhu, *Queues and Inventories*, John Wiley & Sons.

21. L. Kleinrock, *Queueing Systems*, Wiley-Interscience.

22. G. Geoffrey, *System Simulation*, PHI.

23. W. D. Kelton, R. Sadowski, and D. Sadowski, *Simulation with Arena*, McGraw-Hill.

24. J. Banks, J. S. Carson II, B. L. Nelson, and D. M. Nicol, *Discrete-Event System Simulation*, Pearson.

PROGRAMMING TECHNIQUES & DATA STRUCTURES (50)

Programming Techniques and Structures (16)

Programming paradigms, structural programming concepts, object oriented programming concepts; Introduction to C/Python language; File handling; Asymptotic Notations.

Data Structures (18)

Formal definitions, operations, implementations and applications of basic data structures; array, stack, queue, dequeue, priority queue, linked lists, doubly linked list, binary tree and traversal algorithms, threaded binary tree; Implementation.

Search Techniques (8)

Binary search, Fibonacci search, binary search tree, height balanced tree, heap, AVL tree, B-tree, hashing techniques; Implementation.

Sorting Techniques (8)

Bubble sort, insertion sort, heap sort, merge and quick sort. External sorting techniques; Implementation

Programming Assignments

References

1. B. W. Kernighan and D. M. Ritchie, *The C Programming Language*, Pearson.
2. E. Horowitz and S. Sahni, *Fundamentals of Data Structures*, Universities Press.
3. A. M. Tanenbaum, Y. Langsam, and M. J. Augenstein, *Data Structures Using C*, Pearson.
4. M. T. Goodrich, R. Tamassia, and M. H. Goldwasser, *Data Structures and Algorithms in Python*, Wiley.
5. T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, *Introduction to Algorithms*, MIT Press.

QUALITY MANAGEMENT (50)

Introduction to Quality and Quality Management (6)

Historical evolution of quality management. Concepts of quality and quality management. Different definitions, dimensions and views of quality. Quality and profitability. Importance of quality management.

Contribution of Eminent Quality Experts (4)

Contribution to quality management by eminent quality experts, like Armand V. Fiegenbaum, Genichi Taguchi, Joseph Juran, Kaoru Ishikawa, Philip Crosby, Shigeo Shingo, W. Edwards Deming, and Walter A. Shewhart.

Different Models of Quality Management (2)

Concept of Quality management models. Introduction to models like MBNQA and EFQM.

Customer Satisfaction Models (4)

Concepts of customers, internal and external. Chain of internal customers to deliver value to the external customers. Concepts of customer satisfaction and dissatisfaction. Different Customer Satisfaction Models.

Concepts of Service Quality (2)

Service quality dimensions and SERVQUAL. Critiques of SERVQUAL and some alternatives.

Cost of Quality and Quality Loss Function (4)

Definition and components of costs of quality. Identification of different costs. The cost of quality model. Quality loss function proposed by Taguchi. Taguchi robust design approach and signal-to-noise ratio.

Quality Management Improvement Initiatives and Tools (10)

Concepts of quantitative, process based improvement. Introduction to different types of processes. Process flow and Process maps and their usage in quality management. Introduction to Quality Function Deployment (QFD), SWOT Analysis, Failure Mode and Effect Analysis (FMEA). Overview of six-sigma and lean six-sigma.

Management Systems (16)

What is International Organization for Standardization (ISO) and its roll in developing various international standards. Quality management principles. Important management systems, like ISO 9001 quality management system, ISO 14001 environment management system, ISO 45001 occupational health and safety management system, ISO 26000 social

accountability management system and ISO 27001 Information security, cybersecurity and privacy protection management system.

Industry 4.0 (2)

Introduction to Fourth industrial revolution (I4.0). Various digital technologies - connectivity, advanced analytics, robotics and automation. Understanding Quality Management developments due to increased digitalization.

References

1. J. M. Juran, *A History of Managing for Quality: The Evolution, Trends, and Future Directions of Managing for Quality*, ASQC/Quality Press.
2. J. M. Juran and F. M. Gryna, *Quality Planning and Analysis*, Tata McGraw-Hill.
3. H. S. Gitlow, *Quality Management*, McGraw Hill India.
4. V. A. Zeithaml, A. Parasuraman, and L. L. Berry, *Delivering Service Quality*, The Free Press, New York.
5. M. Harry and R. Schroeder, *Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations*.
6. M. J. Harry, P. S. Mann, O. de Hodgins, C. Lacke, and R. Hulbert, *Practitioner's Guide for Statistics and Lean Six Sigma for Process Improvements*, Wiley.
7. D. C. S. Summers, *Lean Six Sigma: Process Improvement Tools and Techniques*, Prentice Hall.

ELECTRICAL AND ELECTRONICS ENGINEERING (50)

Basic Electrical Systems & Control (25)

Steady Current (6) Ohm's law, Resistive circuits, Kirchhoff's law, Thevenin's theorem, Norton's theorem, delta to star and star to delta transformation, maximum power transfer theorem.

D.C. Circuits (6) Steady state response, transient response, D.C. responses of inductance and capacitance, series RL circuit, series RC circuit, series RLC circuit, principles of D.C. motors and generators.

A.C. Circuits (7) A.C. response of resistance, inductance and capacitance, average value and root mean square value, sinusoidal voltage applied to series RL, RC and RLC circuits, series resonance, parallel resonance, transformers, principles of A.C. motors.

Electromagnetic Induction (3) Principles of electromagnetic induction, self-inductance, mutual inductance, inductances in series and parallel, coefficient of coupling.

Control Systems (3) Feedback and feedforward control, automatic control system, parameters of control system, proportional control system, proportional plus derivative control system, proportional plus derivative plus integral control system, stability of control systems.

Electronics (25)

Semiconductors (4) Electrons and holes, energy band diagram, electron emission, intrinsic and extrinsic semiconductor, p-type and n-type semiconductor, current flow in semiconductors, bias and characteristics of p–n junction, principles of semiconductor diodes.

Junction Transistors (5) n-p-n and p-n-p transistors, transistor characteristics and biasing, modes of operation (CB, CE, CC), alpha and beta of a transistor, hybrid parameters, RC-coupled amplifiers.

Operational Amplifiers (3) Circuit analysis of an op-amp, inverting and non-inverting amplifiers, adder, differential amplifier, differentiator, integrator, weighted resistor D/A converter, R–2R ladder converter.

Feedback Amplifiers (3) Transfer gain, closed-loop gain, open-loop gain, positive and negative feedback, feedback fraction, working procedure of feedback amplifier, stability of gain, oscillators.

Number Systems (4) Decimal, binary and octal number systems, decimal–binary conversion and vice versa, binary addition and subtraction, 1's complement and 2's complement method for subtraction, De Morgan's Theorem.

Digital Circuits (6) "circuit analysis of OR gate, AND gate, NOR gate, NAND gate, exclusive OR gate and exclusive NOR", logic circuit implementation of Boolean expressions,

Karnaugh maps, half adder, full adder, clocked RS flip-flop, JK flip-flop, race around condition, master-slave JK flip-flop, D and T type flip-flop, multiplexer, demultiplexer, decoder, encoder, registers, counters.

References

1. D. Chattopadhyay and P. C. Rakshit. *Electronics Fundamentals and Applications*, New Age International.
2. B. L. Theraja. *Fundamentals of Electrical Engineering and Electronics*, S. Chand Publishing.
3. B. L. Theraja and A. K. Theraja. *Electrical Technology*, S. Chand Publishing.
4. J. D. Ryder. *Electronics Engineering Principles*, McGraw Hill.
5. S. Millman and C. C. Halkias. *Integrated Electronics*, McGraw Hill.
6. G. J. Thaler and R. G. Brown. *Analysis and Design of Feedback Control Systems*, McGraw Hill.
7. J. G. Graeme and T. E. Tobey. *Operational Amplifiers: Design and Applications*, McGraw Hill.
8. A. B. Phillips. *Transistor Engineering*, McGraw Hill.
9. T. P. Sifferlen and V. Vartanian. *Digital Electronics with Engineering Applications*, Prentice Hall.
10. J. D. Ryder. *Networks, Lines and Fields*, Asia Publishing.

ENGINEERING DRAWING & WORKSHOP I (50)

Engineering Drawing (30)

Introduction to International and Indian standards - its role in Engineering Drawing.

Basic concept of orthogonal projection, third angle and first angle projections, scale of drawing and dimensioning, theory of section and conventional sectional view, offset section, revolved section, auxiliary view.

Convention of representing screw threads in a drawing, diametral clearance in bolt holes and their spacing, standard bolt diameters, bolt circle diameter and flange diameter.

Concept of fitting boss and alignment, standard key, key ways and spline, dimensioning parts before assembly and after assembly, Duplication of dimensions and cumulative errors.

Basic Workshop Practices (20)

DC circuits, AC to DC power conversion, Ohm's law, Kirchhoff's laws, Norton's theorem, Thevenin's theorem, AC circuits.

2.2 Second Semester Courses

STOCHASTIC PROCESSES (50)

Concept of a Stochastic Process (4)

State space and parameter space. Examples of various types of stochastic processes.

Discrete Time Parameter, Time Homogeneous Markov Chains (24)

Markov chain, Transition probabilities, Chapman-Kolmogorov equations, First passage time, Communication among states. Classification of states. Definition of recurrence, transience, positive and null recurrence, periodicity. Stability of Markov chain. Limiting probabilities. Absorption probabilities. Illustration with examples of Markov chains: 2-state chains; Birth and Death chain, Random walk, Gambler's ruin chain etc.

Continuous Time Stochastic Processes (22)

Introduction to general continuous time Markov chains. Kolmogorov differential equations.

Poisson process and its properties. Inter-event times and their distributions; Nonhomogeneous Poisson process. Applications of HPP and NHPP. Compound Poisson Processes.

Birth and death processes. Applications of birth and death processes to queuing theory and industrial problems.

References

1. S. Ross. *Stochastic Processes*, John Wiley.

2. S. Karlin. *A First Course in Stochastic Processes*, Academic Press.

3. J. Medhi. *Stochastic Processes*, Wiley Eastern Limited.

4. U. N. Bhatt and K. G. Miller. *Elements of Applied Stochastic Processes*, Wiley, New York.

5. K. L. Chung. *Elementary Probability Theory with Stochastic Processes*, Springer, New York.

STATISTICAL METHODS II (50)

Tests of Hypotheses (14)

Principles of statistical inference. Formulation of the problems with examples. Null and alternative hypotheses. Simple and composite hypotheses. Type I and type II errors, level of significance, power of a test, p-value. Neyman–Pearson Lemma, Most powerful test and uniformly most powerful test. Likelihood ratio test. Testing of mean and variance of normal population (one sample and two samples). Exact and asymptotic tests of proportions.

Relationship of confidence intervals with tests of hypothesis. Chi-squared test for goodness of fit, $r \times c$ contingency tables, χ^2-test for independence and homogeneity.

Linear Statistical Models (6)

Definition of linear model. Gauss-Markov Theorem. One-way and two-way ANOVA models. ANCOVA - one way classification with single covariate.

Non-parametric Inference (8)

Formulation of the problems. Comparison with parametric inference. Use of order statistics. Confidence interval for quantiles. Sign test, Wilcoxon signed rank test, Mann-Whitney test, Run test. Spearman's and Kendall's tests. Kruska–Wallis test, Friedman test, Kolmogorov-Smirnov test, Anderson-Darling test for normality.

Experimental Design (22)

Basic concepts of experimental design. Concepts of experimental unit, experimental error, factor, levels, treatments, treatment combinations and interaction. Fixed and random factors. Basic principles of experimentation. Contrasts and orthogonal contrasts. Concept of

orthogonality of data.

Completely Randomized Design, Randomized Complete Block Design, Latin Square Design.

Factorial designs: 2^k and 3^k factorial designs. Confounding in 2^k and 3^k factorial design. Concept of partial confounding. Two-level and three-level fractional factorial designs.

Illustration with specific examples and numerical exercises using statistical packages `R/Python`.

References

1. D. C. Montgomery & G. C. Runger. *Applied Statistics and Probability for Engineers*, John Wiley and Sons, New York.
2. H. Lee. *Foundations of Applied Statistical Methods*, Springer.
3. G. K. Bhattacharya & R. A. Johnson. *Statistical Concepts & Methods*, John Wiley & Sons.
4. J. A. Rice. *Mathematical Statistics and Data Analysis*, Cengage Learning.
5. W. J. Conover. *Practical Nonparametric Statistics*, Wiley.
6. W. M. Mendenhall & T. L. Sincich. *Statistics for Engineering and the Sciences*, CRC Press.
7. A. M. Gun, M. K. Gupta & B. Dasgupta. *Fundamentals of Statistics: Volume I*, World Press.
8. M. Gun, M. K. Gupta & B. Dasgupta. *An Outline of Statistical Theory: Volume II*, World Press.
9. E. J. Dudewicz & S. N. Mishra. *Modern Mathematical Statistics*, Wiley.
10. D. C. Montgomery. *Design and Analysis of Experiments*, John Wiley, New York.
11. G. E. P. Box, W. G. Hunter & J. S. Hunter. *Statistics for Experimenters: An Introduction to Design, Data Analysis and Model Building*, John Wiley, New York.
12. W. G. Cochran & G. M. Cox. *Experimental Designs*, John Wiley, New York.

REGRESSION AND TIME SERIES ANALYSES (50)

Regression Analysis (34)

Simple linear regression, Estimation of parameters, Properties of least square estimators, Estimation of error variance, Confidence intervals, Prediction interval.

Multivariate data, Multiple linear regression, Properties of least square estimators, Estimation of error variance, Confidence intervals, Prediction interval, Multiple and partial correlation. Forward, backward and stepwise regression; different methods for subset selection. Cross validation.

Validation of model assumptions. Detection of outliers, influential observation, heteroscedasticity, nonlinearity, nonnormality and serial correlation.

Collinearity: detection of collinearity, consequences. Remedies of multicollinearity: Ridge, Principal Component Regression. LASSO and Elastic Net.

Logistic regression.

Time Series Analysis (16)

Elements of Time Series analysis: Trend/secular, seasonal/cyclic and random components of a time series, Stationarity, time average, ACF and PACF, correlogram and periodogram. MA, AR, ARMA and ARIMA processes. Identification, estimation and various specification tests. Forecast and its properties.

Illustration with specific examples and numerical exercises using statistical packages `R/Python`.

References

1. D. C. Montgomery & E. Peck. *Introduction to Linear Regression Analysis*, Wiley.
2. N. R. Draper & H. Smith. *Applied Regression Analysis*, Wiley.
3. F. A. Graybill & H. K. Iyer. *Regression Analysis: Concepts and Applications*.
4. S. Chatterjee & A. S. Hadi. *Regression Analysis by Example*, Wiley.
5. S. J. Seather. *A Modern Approach to Regression with R*, Springer.

6. D. W. Hosmer Jr., S. Lemeshow & R. X. Sturdivant. *Applied Logistic Regression*, Wiley.

7. D. G. Kleinbaum & M. Klein. *Logistic Regression: A Self Learning Text*, Springer.

8. D. C. Montgomery, C. L. Jennings & M. Kulahci. *Introduction to Time Series Analysis and Forecasting*, Wiley.

9. R. H. Shumway & D. S. Stoffer. *Time Series Analysis and Its Application*, Springer.

10. P. J. Brockwell & R. A. Davis. *Introduction to Time Series and Forecasting*, Springer, New York.

11. C. Chatfield. *The Analysis of Time Series*, CRC Press.

RELIABILITY I (50)

Concept of Reliability (4)

Importance of reliability, definition of reliability and its measures. Concept of failure. Fault tree analysis.

System Reliability (14)

Components and systems. Series, parallel, k-out-of-n system (including concept of redundancy) and their reliability block diagrams. Coherent system, path sets and cut sets. Structural importance of components. Modular decomposition of coherent system. Reliability of coherent system with independent components. Reliability importance of components. Stress–strength reliability models. Concept of associated random variables. Bounds on system reliability (results only).

Lifetime Models (14)

Notion of aging, concept of hazard rate for both continuous and discrete life distributions, reliability function and mean residual life. IFR and DFR class of life distributions. Bathtub failure curve. Lifetime distributions: exponential, Weibull, lognormal, gamma, inverse Gaussian. Mixture distribution. Reliability of systems under different lifetime distributions.

Classes of life distributions based on aging properties: IFR, IFRA, DFR, DFRA, NBU, NBUE, NWU, NWUE, DMRL. Relationship between different classes of life distributions. Statement of results on closure properties.

Life Testing and Inference (18)

Life testing. Complete data and censored data. Type-I, Type-II, hybrid, interval and random censoring schemes. Parametric inference based on complete and censored data using asymptotic likelihood theory. Nonparametric estimate (life table and Kaplan-Meier) of reliability. Graphical methods (PP, QQ plots) and standard statistical tests for model validation. Analysis of field data.

References

1. R. E. Barlow & F. Proschan. *Statistical Theory of Reliability and Life Testing Probability Models*, Holt, Rinehart and Winston, New York.

2. A. Hoyland & M. Rausand. *System Reliability Theory: Models and Statistical Methods*, John Wiley, New York.

3. K. C. Kapur & L. R. Lamberson. *Reliability in Engineering Design*, John Wiley, New York.

4. M. Modarres, M. P. Kaminskiy & V. Krivtsov. *Reliability Engineering and Risk Analysis*, CRC Press.

5. W. Q. Meeker & L. A. Escobar. *Statistical Methods for Reliability Data*, John Wiley, New York.

6. S. C. Saunders. *Reliability, Life Testing and Prediction of Service Lives*, Springer.

7. J. F. Lawless. *Statistical Models and Methods for Lifetime Data*, Wiley, New York.

8. J. V. Deshpande & S. G. Purohit. *Life Time Data: Statistical Models and Methods*, World Scientific, Singapore.

9. W. Nelson. *Applied Life Data Analysis*, Wiley, New York.

10. D. H. Stamatis. *Failure Mode & Effect Analysis: FMEA from Theory to Execution*, ASQ Quality Press.

INDUSTRIAL ENGINEERING & SUPPLY CHAIN MANAGEMENT (50)

INDUSTRIAL ENGINEERING (20)

Operations Management (8)

Operations management, operations strategy.

Method. Methods study: recording techniques, critical examination, and development of alternative and implementation. Examples: estimation of task times by past data approach, direct time study approach, predetermined time standards approach, work sampling approach.

Machine. Equipment selection, techniques and replacement strategies, examples; breakdown, preventive and predictive maintenance, scheduling.

Man Management: (2)

Incentive schemes, job specification, job evaluation, work and job design.

Material Management (6)

Planning and control of material: managing demand, material requirement planning, capacity planning, value engineering and analysis.

Plant Management (4)

Plant location, plant layout, and materials handling.

SUPPLY CHAIN MANAGEMENT (30)

Basics of supply chains (6)

Understanding the supply chain, supply chain management, supply chain performance, supply chain drivers and metrics.

Supply chain network design (6)

Designing distribution networks and applications to online sales, network design in the supply chain and transportation in a supply chain.

Managing demand and supply in a supply chain (6)

Demand forecasting in a supply chain, aggregate planning in a supply chain and managing economies of scale in a supply chain.

Finance and marketing in supply chain management (6)

Funding flow and cash flow, scope and functions, structure and components of balance sheet, important terms order-to-cash (O2C) process, purchase-to-pay (P2P) process, working capital management, risk management, role of marketing in supply chain, supply chain market research.

Recent trends in supply chain (6)

Sustainability and supply chain, blockchain technology in supply chain, AI and ML in supply chain.

References

1. P. R. Banga, S. C. Sharma, and N. K. Agrawal, *Industrial Engineering and Management Science*, Khanna Publishers.
2. L. J. Krajewski, L. P. Ritzman, and M. Malhotra, *Operations Management: Strategy and Analysis*, Pearson Education.
3. T. Arnold, *Introduction to Materials Management*, Prentice Hall.
4. D. M. Miller and J. W. Schmidt, *Industrial Engineering and Operations Research*, John Wiley, New York.
5. W. N. Benjamin, *Motion and Time Study*, Irwin, Homewood, IL.
6. K. B. Zandin, *Maynard's Industrial Engineering Handbook*, McGraw-Hill, New York.
7. C. W. Lytle, *Job Evaluation Methods*, Legare Street Press.
8. G. Kanawaty, *Introduction to Work Study*, International Labour Organisation, Geneva, Switzerland.
9. H. Koontz and C. O'Donnell, *Management: A System and Contingency Analysis of Managerial Functions*, McGraw-Hill Book Company, New York.

10. D. J. Luck and R. S. Rubin, *Market Research*, Prentice Hall.

11. H. W. Blyd, R. Westfall, and S. F. Stasch, *Market Research: Text and Cases*, Richard Allwyn Inc., IL.

12. J. C. Van Horne and S. Dhamija, *Financial Management and Policy*, Pearson Education India.

13. P. Chandra, *Financial Management: Theory & Practice*, Tata McGraw-Hill (India).

14. S. Chopra, P. Meindl, and D. V. Kalra, *Supply Chain Management: Strategy, Planning, and Operation*, Pearson.

15. R. S. Russell and B. W. Taylor, *Operations and Supply Chain Management*, John Wiley and Sons, Inc.

16. G. T. Hult, D. Closs, and D. Frayer, *Global Supply Chain Management: Leveraging Processes, Measurements, and Tools for Strategic Corporate Advantage*, McGraw-Hill Education.

MECHANICAL ENGINEERING (50)

Mechanical Properties of Materials (12)

Brittleness, ductility, toughness, Engineering and true stress strain curves, Instability in tension, yielding criteria for ductile materials, tensile properties, anisotropy, Torsional properties, Hardness, Impact strength, Fatigue and Creep behaviors at low and elevated temperature.

Metrology (10)

Objectives of Metrology, Characteristics of measuring instruments, Functional elements of instruments, classification of methods of measurement.

Standards for measurement and standardizing organizations, International system (SI) of units. Measurement uncertainty/error, types of error, methods of estimating total uncertainty in a measurement process.

Limits, Fits and Dimensional and Geometric Tolerances. Surface roughness measurement.

Machining (10)

Various machining methods and machine tools for metal cutting. Influence of various actors like speed, feed and depth of cut on tool life. Economic tool life, various angles and geometry of single point cutting tools (ISO standard).

Nonconventional machining and CNC machines.

Mechanical Working of Metals (8)

Plastic deformation of metals, Hot and cold working, Forging, Rolling, Extrusion, Wire drawing, Deep drawing, Stretch forming, Blanking, Piercing, Bending. Hydro-forming and explosive forming.

Mechanical Power and Prime Movers (10)

Elements of thermal and hydro power plants, Pumps, Compressors, Heat Pumps and IC Engines, Efficiency and performance of thermo-fluid machineries and plants, Renewable energy and sustainability.

References

1. S. Timoshenko. *Strength of materials*, CBS Publishers & Distributors.
2. HMT. *Production Technology*, Tata McGraw-Hill.
3. H. W. Pollack. *Manufacturing and Machine Tool Operation*, Prentice Hall, NY.
4. R. M. Brick, A. W. Pouse & R. B. Gorden. *Structure and Properties of Engineering Materials*, McGraw-Hill.
5. W. A. J. Chapman. *Workshop Technology, Parts 1, 2, 3*, ELBS.
6. G. C. Sen & A. Bhattacharya. *Principles of Machine Tools*, New Central Book Agency (P) Ltd.
7. R. K. Springborn (Ed.). *Nontraditional Machining Process*, ASTM.
8. R. K. Jain. *Engineering Metrology*, Khanna, New Delhi.
9. E. O. Doebelin. *Measurement Systems: Application and Design*, McGraw-Hill.
10. L. Miller. *Engineering Dimensional Metrology*, E. Arnold.

11. S. Singh & S. Pati. *Thermal Engineering*, Pearson.

12. D. K. Mandal, S. Chakrabarti, A. K. Das & P. K. Das. *Power Plant Engineering*, Pearson.

WORKSHOP II (50)

Instrumentation / Digital Electronics (20)

Elementary electronics (including amplifiers, transistors, oscillators, op-amp circuits), diode, digital electronic circuits along with different kinds of logic gates.

Material Testing (6)

Rockwell hardness tests, Brinell hardness tests.

Metrology and Machining Practices (24)

Vernier caliper, speedometer, gauge, micrometer, lathe machining, shaping, milling, drilling.

2.3 Third Semester Compulsory Courses

OPERATIONS RESEARCH II (50)

Integer Programming (8)

Formulation of various problems as integer and mixed integer programming problems, branch and bound algorithm, cutting plane method for pure and mixed integer programming problems.

Nonlinear Programming (22)

Introduction to nonlinear programming, convex function and its generalization, unconstraint and constraint optimization, KKT necessary and sufficient conditions for optimality, linear complementarity problem and Lemke's complementary pivot algorithm, quadratic programming and algorithm for solving quadratic programming problem, separable programming, linear fractional programming.

Game Theory and Decisions Making (10)

Game theory to determine strategic behavior, elements of decision theory and decision trees, elements of cooperative and non-cooperative games, two-person zero-sum game, bimatrix games and Lemke's algorithm for solving bimatrix games.

Network Optimization Models (10)

Types of network problems with examples, flows in network, max-flow min-cut theorem and its application, Ford-Fulkerson method, concept of graph theory.

References

1. R. S. Garfinkel & G. L. Nemhauser. *Integer Programming*, John Wiley.
2. H. M. Taha. *Integer Programming: Theory, Applications and Computations*, Academic Press.
3. M. S. Bazaraa, H. D. Sherali & C. M. Shetty. *Nonlinear Programming: Theory and Algorithms*, John Wiley.
4. W. I. Zangwill. *Nonlinear Programming*, Prentice Hall.
5. R. Fletcher. *Practical Methods of Optimization*, John Wiley.
6. J. O. Berger. *Statistical Decision Theory*, Springer Verlag.
7. G. Owen. *Game Theory*, Academic Press.
8. R. D. Archibald. *Network based Management Systems*, John Wiley.
9. A. Battersby. *Network Analysis for Planning and Scheduling*, Macmillan.
10. M. S. Bazaraa, J. J. Jarvis & H. D. Sherali. *Linear Programming and Network flows*, John Wiley.
11. R. B. Bapat. *Graphs and Matrices*, Springer.

RELIABILITY II (50)

Regression Analysis of Lifetime Data (8)

Accelerated failure-time model and proportional hazard models.

Accelerated Life Testing (6)

Basics of accelerated life testing; acceleration factor and method: use-rate, temperature, voltage; Arrehenius model, Eyring model, inverse power model; step-stress accelerated life test.

Reliability and Availability of Repairable Components and Systems (20)

Repair Models: Perfect, imperfect repairs. Modelling failure processes: HPP, NHPP and renewal process. Inferential results on HPP and NHPP. Analysis of data from repairable system.

Up-time and down-time. Availability function, average availability and limiting availability of components and coherent systems. Reliability/availability of repairable standby systems.

Maintainability, corrective maintenance, preventive maintenance and predictive maintenance.

Reliability Optimization (4)

Optimal spare part allocation, Generalized Kettelle's algorithm.

Warranty analysis (8)

Introduction, Types of warranties: Free replacement warranty, Pro-rata warranty, Combined free replacement warranty and pro-rata warranty, Lump-sum payment type of warranty. Warranty costs based on a single failure during the warranty period, warranty analysis considering multiple failures during warranty period. Optimum warranty period, Two-dimensional warranties.

Software Reliability (4)

Introduction to software reliability modelling, software failure, software fault, basic concept and definition. Difference between hardware and software reliability, Jelinski-Moranda model and some other relevant models. Optimal software release problem.

References

1. R. E. Barlow & F. Proschan. *Statistical Theory of Reliability and Life Testing Probability Models*, Holt, Rinehart and Winston, New York.
2. A. Hoyland & M. Rausand. *System Reliability Theory: Models and Statistical Methods*, John Wiley, New York.
3. H. Ascher & H. Feingold. *Repairable System Reliability*, Marcel Dekker, New York.
4. S. E. Rigdon & A. P. Basu. *Statistical Methods for the Reliability of Repairable Systems*, John Wiley, New York.

5. M. Modarres, M. P. Kaminskiy & V. Krivtsov. *Reliability Engineering and Risk Analysis*, CRC Press.

6. W. Q. Meeker & L. A. Escobar. *Statistical Methods for Reliability Data*, John Wiley, New York.

7. J. F. Lawless. *Statistical Models and Methods for Lifetime Data*, Wiley, New York.

8. J. V. Deshpande & S. G. Purohit. *Life Time Data: Statistical Models and Methods*, World Scientific, Singapore.

9. W. R. Blischke, M. R. Karim & D. N. P. Murthy. *Warranty Analysis and Data Collection*, Springer.

10. H. Pham. *Software Reliability*, Springer-Verlag.

11. S. Yamada. *Software Reliability Modeling- Fundamentals and Applications*, Springer-Tokyo.

STATISTICAL QUALITY CONTROL (50)

Introduction to SQC (6)

Dimensions of quality for manufacturing & service sectors, quality definition, stratification, check sheet, Pareto analysis, Ishikawa diagram, box plot & schematic box plot, concept of common & special causes of variation, type I & type II errors, concept of rational subgroup, Juran's feedback control, Deming's PDCA/PDSA.

SPC Techniques (32)

$\bar{X}$–R chart, $\bar{X}$–S chart, X–MR chart, p-chart, np-chart, c-chart, u-chart, demerit system, sloping control chart, operating characteristic functions of X chart & R-chart, average run length function of Shewhart control chart, Exponentially Weighted Moving Average (EWMA) control chart, Cumulative Sum (CUSUM) control chart, economic process centering, Taguchi's beta-correction methodology, tolerancing, gage repeatability & reproducibility study for measurable data, kappa index for attribute data. Process capability indices - C_p, C_{pk}, C_{pm}, C_{pmk} and other indices (P_p, P_{pk}), confidence intervals for process capability indices, relationships between process capability indices and product conformance/non-conformance in a process; process capability analysis for skewed data. Monitoring of short run processes, monitoring of auto correlated quality characteristics, multivariate control chart.

Acceptance Sampling (12)

Purpose of acceptance sampling; advantages & disadvantages of acceptance sampling; definitions of AOQ, AOQL, AQL, ASN, ATI, LTPD, producer's risk, consumer's risk; type A & type B OC curves; basic awareness about various acceptance sampling plans; single sampling plan for attributes & its OC curve, mathematical relationships of probability of acceptance of a lot with acceptance number (c), sample size (n) and proportion of defectives (p), double sampling plan for attributes & its OC curve, ASN for double sampling plans, designing a single and double sampling plan with a specified OC curve, the concepts of AOQ, AOQL, ATI & the related formulae in case of rectifying single and double sampling plans. Usage of MIL.STD.105-D; Dodge–Romig sampling inspection tables for single and double sampling. Chain sampling plan, continuous sampling plan, skip-lot sampling plan, introduction to variable sampling plan (MIL.STD.414).

References

1. E. L. Grant and R. S. Leavenworth. *Statistical Quality Control*, McGraw Hill, New York.
2. A. J. Duncan. *Quality Control and Industrial Statistics*, Richard D. Irwin, Homewood.
3. D. C. Montgomery. *Introduction to Statistical Quality Control*, Wiley India.
4. J. Banks. *Principle of Quality Control*, John Wiley & Sons.

2.4 Third Semester Elective Courses

MACHINE LEARNING (50)

Basics (2)

Overview of supervised, unsupervised, and reinforcement learning paradigms. Similarity and dissimilarity measures.

Classification and Regression (14)

Data pre-processing: normalization, standardization, dimensional consistency.
Distance metrics: Euclidean, Mahalanobis.

Algorithms:

k-Nearest Neighbors (k-NN), Naive Bayes, Kernel density-based methods

Logistic Regression, Support Vector Machines (SVMs), Decision Trees

Linear and Non-linear Regression Models

Model evaluation: Confusion matrix, ROC-AUC, precision, recall, F1 score, cross-validation.

Ensemble Methods (4)

Concepts of model ensembling: variance reduction and boosting.
Algorithms:

Bagging and Random Forests

Boosting methods: AdaBoost, Gradient Boosting Machines (GBM), XGBoost

Clustering (8)

Algorithms:

Hierarchical clustering,

Partitional clustering: K-means, Gaussian Mixture Models (GMMs).

Density-based methods: DBSCAN

Fuzzy clustering

Cluster validation: Silhouette coefficient, Dunn index.

Dimensionality Reduction (6)

Feature selection techniques: Filter, Wrapper, and Embedded methods etc.
Feature extraction techniques:

Linear: Principal component analysis (PCA), Linear discriminant analysis (LDA), Factor analysis and Singular value decomposition (SVD) etc.

Non-linear: t-SNE, Isomap, Autoencoders etc.

Deep Learning and Advanced Topics (16)

Foundations of deep learning and representation learning.

Neural network architectures, Fully Connected Networks, Convolutional Neural Networks (CNNs), Long Short-Term Memory (LSTM) Networks, Transformer architecture.

Recent trends and applications: Basics of Large Language Models (LLMs): Fine Tuning, attention mechanisms etc. and other advanced topics.

References

1. T. M. Mitchell, Machine Learning. McGraw-Hill International Edition, 1997.
2. R. O. Duda, P. E. Hart & D. G. Stork. Pattern Classification, Wiley 2000.
3. T. H. R.Tibshirani & J. Friedman. The Elements of Statistical Learning (2nd Edition), Springer.
4. C. M. Bishop. Pattern recognition and Machine Learning, Springer, 2006.
5. I. Goodfellow, Y. Bengio & A.Courville. Deep Learning, MIT Press, 2016.
6. Francois Cholle, .Deep learning with Python. simon and schuster, 2021.
7. Bernhard Scholkopf and Alexander J. Smola. Learning with Kernels: Support Vector Machines, Regularization, Optimization, and Beyond. MIT Press, Cambridge, MA, USA, 2001.
8. Kevin P. Murphy. Machine Learning: A Probabilistic Perspective. The MIT Press, 2012.

BUSINESS ANALYTICS (50)

Introduction to Analytics (6)

Introduction to usual decision making process and need for data driven decisions; examples of applications of analytics in different domains like HR, sales and marketing, operations, supply chain and in different business verticals like retail, health care, banking and financial services, manufacturing etc.

Analytics, Data Quality and Decision Making (8)

Concepts of Business problems, its challenges and looking through analytics; relationship between Business Intelligence and Business Analytics; Broad tasks of analytics; Data - traditional vs. analytics view; Big Data - characteristics and challenges; Data Quality - dimensions and measurement metric; Data Lake vs. Data Warehouse; Data Science - principles and relationship with analytics.

Preparatory Analytics (6)

Pre-processing of data - various methods: Data Cleaning, Data Transformation and Data Reduction; Examples.

Visual Analytics (8)

Applicability of Data visualization, single variate and multivariate Data visualization techniques, Introduction to data visualization dashboard and related application of visualization techniques.

Predictive Analytics (12)

Basics Concepts. Decision Trees, k-NN, Rule Induction, Naïve Bayes, Support Vector Machine (SVM), Ensemble Learners (Bagging, Boosting, AdaBoost, XGBoost, Random Forest), Logistics Regression, Generalized Additive Models, Structural equation modelling (SEM) and Path models, ANN, Bayesian Networks, Association Rule Mining (ARM) and Apriori algorithms; Examples with Cases.

Prescriptive Analytics (10)

Introduction to Decision Making (DM), Broad methods of DM - mathematical, statistical, evolutionary, MCDM/MADM, hybrid; Multi-objective scenarios; Markov decision process; Classical vs. Evolutionary optimizations (ex. Goal programming, Genetic algorithm); Statistical methods - multi response surface methodology, desirability function based optimization; Taguchi's loss function & SN-ratio based methods; MCDM/MADM, few instances of hybrid methods for decision making. Examples with Cases.

Analytics based Projects.

References

1. U. D. Kumar. *Business Analytics: The Science of Data-Driven Decision Making*, Second Edition.

2. E. Siegel. *Predictive Analytics: The Power to Predict*, Second Edition.

3. F. Provost and T. Fawcett. *Data Science for Business: What You Need to Know about Data Mining and Data-Analytic Thinking*.

4. P. C. Bruce, G. Shmueli and N. R. Patel. *Data Mining for Business Intelligence: Concepts, Techniques and Applications*, Wiley.

5. R. Sharda, D. Delen and E. Turban. *Business Intelligence, Analytics, and Data Science*, Fourth Edition, Pearson.

DATABASE MANAGEMENT SYSTEMS (50)

Introduction (2)

Introduction to Database, Hierarchical, Network and Relational Models.

Database System Architecture (2)

Data Models, Schemas and Instances, Database manager, DBMS Languages, Overall Database System Environment.

Storage Strategies (2)

Sequential File Organization, buffer management, mapping tables, ISAM file, Use of B-tree and B+ tree for indexing, Hashing and Hash functions.

Entity Relationship Model (8)

Entities and entity sets, Relationship and relationship sets, Mapping constraints, ER Diagram, EER Diagram, Reducing ER/EER diagram to tables, Generalization and Specialization, Aggregation.

Relational Database Design (8)

Domain and data dependency, Armstrong's axioms, Functional Dependencies, Normal forms, Dependency preservation, Lossless design.

Relational Query languages (12)

Relational algebra, Tuple and domain relational calculus, SQL, DDL and DML constructs.

Query Processing and Optimization (8)

Evaluation of relational algebra expressions, Cost estimation for processing a query, Query equivalence, Join strategies, Query optimization algorithms.

Transaction Processing and Concurrency Control (8)

Concurrency control, ACID property, Serializability of scheduling, Locking and timestamp based schedulers, Multi-version and optimistic Concurrency Control schemes, Database recovery.

SQL assignments.

References

1. A. Silberschatz, H. F. Korth& S. Sudarshan. Database System Concepts, McGraw-Hill.
2. C. J. Date, A. Kannan & S. Swamynathan. An Introduction to Database Systems, Pearson.
3. R. Elmasri & S. B. Navathe. Database Systems: Models, Languages, Design and Application Programming, Jain Book Agency.
4. R. Ramakrishnan & J. Gehrke. Database Management Systems, McGraw-Hill.
5. H. Garcia-Molina, J. Ullman, J. Widom & J. D. Ullman. Database Systems: The Complete Boo, Pearson.

QUANTITATIVE FINANCE (50)

Basic Concepts (15)

Arbitrage, Principle of no arbitrage, Law of one price; Frictionless / Efficient market, Transaction cost, Contingent contracts, Concept of complete market.

Time value of money, discounting: deterministic and stochastic; Martingale, Risk neutral valuation, Equivalent martingale measure.

Mean - Variance utility / Normal distributed returns; Capital Asset Pricing Model (CAPM), Extensions, test for efficiency.

Contracts and Combinations (15)

Contracts: Forwards, Futures, Options (Call, Put, European, American, Exotics). Combinations; Risk neutral portfolio construction.

Valuation (15)

Valuation of contracts in discrete time models. Computation using Binomial tree.

Methods in Quantitative Finance (15)

Brownian motion, Stochastic Integration and Ito's formula, Black Scholes option pricing and hedging, Girsanov's Theorem.

References

1. S. R. Pliska. Introduction to Mathematical Finance: Discrete Time Models, Wiley.
2. J. C. Hull. Options, Futures, and Other Derivatives, Pearson.
3. P. G. Hoel, S. C. Port & C. J. Stone. Introduction to Stochastic Processes, Houghton Mifflin Company, Boston.
4. B. Oksendal. Stochastic Differential Equations: An Introduction with Applications, Springer Link.

INDUSTRIAL EXPERIMENTATION (50)

Balanced Incomplete Block Design (BIBD) (6)

Analysis and applications

Nested and Split Plot Designs (6)

Two stage nested design. General m-stage nested designs. Design with nested and crossed factors. Split-plot design, their use and analysis.

Orthogonal Arrays and Taguchi's Linear Graphs (10)

Orthogonal arrays, Linear graphs and their applications, Different types of 2 and 3 level orthogonal arrays. Multilevel arrangement. Pseudo-factor designs.

Response Surface Methodology (8)

Introduction, Method of steepest ascent. Analysis of second-order surface. Response surface designs for first order and second order models. Optimal designs.

Robust Design Concepts (6)

Background and Taguchi's concepts of robust design. Parameter design. Inner array and outer array. Signal to noise ratios. Response surface approach to robust design.

Mixture Design (6)

Introduction, Simplex Design and Canonical mixture polynomial, simplex lattice design and Simplex centroid designs – augmenting with axial runs. Constrained mixture design, D-Optimal design, Distance based design, Response surface modelling. Mixture experiment with process variables.

Online Experiments (8)

Concept of online experiments, A/B testing, factorial designs for online experiments, design for multi-platform experiments.

References

1. D.C. Montgomery. Design and Analysis of experiments, John Wiley, N.Y.
2. G. E. P. Box, J. S. Hunter & W. G. Hunter. Statistics for Experimenters, Wiley.
3. W.G. Cochran & G.M. Cox. Experimental Designs, Wiley, N.Y.
4. G. E. P. Box & N. R. Draper. Empirical Model Building and Response Surfaces, John Wiley.
5. R. H. Myers & D. C. Montgomery. Response Surface Methodology: Process and Product Optimization Using Designed Experiments, John Wiley, New York.
6. G. Taguchi. Introduction to Off-line Quality Control, Central Japan Quality Control Association, Nagoya, Japan.
7. P. J. Ross. Taguchi Techniques for Quality Engineering: Loss Function, Orthogonal Experiments, Parameter and Tolerance Design, McGraw-Hill, New York.
8. W. P. Gardiner & G. Gettinby. Experimental Design Techniques in Statistical Practice: A Practical Software-Based Approach, Horwood Publishing, Chichester.
9. A. C. Atkinson & A. N. Donev. Optimum Experimental Designs, Clarendon Press, Oxford.
10. T. J. Santner, B. J. Williams & W. I. Notz. The Design and Analysis of Computer Experiments, Springer.

APPLIED MULTIVARIATE ANALYSIS (50)

Introduction (4)

Multivariate data, objectives of multivariate data analysis. Multivariate data visualization.

Multivariate Normal Distribution (14)

Multivariate normal distribution and its properties. Estimation in the multivariate normal. Assessing multivariate normality. Wishert Distribution (definition, properties). Hotelling's T^2 test. Test for mean of multivariate normal distribution: single and two samples with known and unknown dispersion matrix. MANOVA. Tests on covariance matrices - tests of equality of covariate matrices, test of independence.

Multivariate Multiple Regression (6)

The multivariate linear model, Least Squares estimation in the multivariate model, prediction.

Principal Component and Factor Analysis (8)

Derivation of principal components. Interpretation of principal components. Factor analysis model: extracting common factors, factor rotation, interpretation of factors.

Discrimination and Classification (8)

Motivation. Fisher's linear discriminant function, discriminant analysis for several groups. Classification into two /several normal groups. Estimating misclassification rates.

Cluster Analysis (6)

Distance measures. Types of clustering. Clustering by hierarchical and partitioning methods. K-means clustering.

Correspondence Analysis (4)

Introduction, row and column profiles, coordinates for plotting row and column, inertia, interpretation.

Illustration with specific examples and numerical exercises using statistical packages `R/Python`.

References

1. C. Rencher and W. F. Christensen. Methods of Multivariate Analysis, Wiley.
2. R. A. Johnson and D. W. Wichern. Applied Multivariate Statistical Data Analysis, Prentice Hall of India Private Limited, New Delhi.
3. T.W. Anderson. An Introduction to Multivariate Statistical Analysis, John Wiley, N.Y.
4. M. S. Srivastava and M. S. Khatri. Methods of Multivariate Statistics, Wiley.
5. D.F. Morrison. Multivariate Statistical Analysis, McGraw Hill, N.Y.

6. B. Everitt and T. Hothorn. An Introduction to Applied Multivariate Analysis with R, Springer New York.

7. B. S. Everitt, S. Landau, M. Leese and D. Stahl. Cluster Analysis, 5th Edition, Wiley.

SIX SIGMA (50)

Overview: Six Sigma and the Organization (18)

Value of six sigma: Recognize why organizations use six sigma, how they apply its philosophy and goals, and the origins of six sigma. Describe how process inputs, outputs, and feedback impact the larger organization; *Organizational drivers and metrics:* Recognize key drivers for business (profit, market share, customer satisfaction, efficiency, product differentiation, learning & growth) and how key metrics and scorecards are developed and impact the entire organization; *Organizational goals and six sigma projects:* Describe the project selection process including the advantages of six sigma improvement methodology (DMAIC) as opposed to other quality management methodologies like TQM etc., and confirm that the project supports and is linked to organizational goals.

Lean concepts and tools: Define and describe concepts such as value chain, flow, pull, perfection etc. and tools commonly used to eliminate waste, including kaizen, 5S, error-proofing, valuestream mapping, overall equipment effectiveness, takt time etc.; Value-added and non-valueadded activities.

Quality function deployment (QFD): Describe how QFD fits into the overall DFSS process; Design and process FMEA; Road maps for DFSS: Describe and distinguish between DMADV (define, measure, analyze, design, verify) and IDOV (identify, design, optimize, verify), identify how they relate to DMAIC and how they help close the loop on improving the end product/process during the design (DFSS) phase.

Define Phase (5)

Process elements (SIPOC diagram, detailed process flow chart etc.); Owners and stakeholders; Identify and classify internal and external customers as applicable to a particular project, and show how projects impact customers; Collect customer data; Analyze customer data; Translate customer requirements: Assist in translating customer feedback into project goals and objectives, including critical to quality (CTQ) attributes and requirements statements. Use voice of the customer analysis tools such as quality function deployment

(QFD) to translate customer requirements into performance measures.

Project charter and problem statement; Project scope; Project metrics (e.g. primary metrics like quality, cycle time, cost and establish key project metrics that relate to the VOC.); Project planning tools (Gantt chart, Pareto prioritization matrix & related indices etc.); Project documentation for phase reviews, management reviews etc.; Project risk analysis including resources, financials, impact on customers and other stakeholders etc.; Project closure.

Define the qualifications, roles and responsibilities of teams including Champion, MBB, BB, GB, Process Owner etc., utilities of brainstorming and related tools and techniques.

Measure Phase (15)

Gage R & R studies for variables; Kappa index for attributes; Six Sigma Metrics for finding long-term, short-term, normalized sigma levels of a process based on throughput yield, rolled throughput yield, TDPU, normalized yield, and DPUNORM.

Analyse Phase (3)

An overview of statistical tools that can be used for root cause analysis like brainstorming, cause & effect diagram, 5-why's techniques, test of hypothesis, ANOVA, regression techniques, orthogonal array experimentation etc.

Improve Phase (4)

Innovation - prioritization approach, concept of solution prioritization matrices; Piloting solution, case example on stratification by Juran; Validating solutions through Box plots, F-test, t-test, FMEA, robust parameter design, Sigma level calculation etc.

Control Phase (5)

Developing a control plan to document and hold the gains and assist in implementing controls and monitoring systems through selection and application of different control charts, Poke Yoke, standardization, standard operating procedures & work instructions, change management & resistance, documentation, control check sheets etc.

References

1. T. Pyzdek and P. A. Keller. *The Six Sigma Handbook: A Complete Guide for Green Belts, Black Belts, and Managers at All Levels*, McGraw Hill.

2. M. Harry and R. Schroeder. *Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations*, Doubleday.

3. S. Barone and E. Lo Franco. *Statistical and Managerial Techniques for Six Sigma Methodology: Theory and Application*, Wiley.

4. M. Harry, P. S. Mann, O. C. De Hodgins, R. L. Hulbert and C. J. Lacke. *Practitioner's Guide to Statistics and Lean Six Sigma for Process Improvements*, Wiley.

5. D. C. S. Summers. *Lean Six Sigma: Process Improvement Tools and Techniques*.

6. K. Muralidharan. *Six Sigma for Organizational Excellence: A Statistical Approach*, Pearson.

2.5 Fourth Semester Curriculum

A ten-week Summer Internship starts immediately after the second semester examinations. The summer internship is for 100 marks, which are carried forward to the fourth Semester. During this semester, every student has to opt for either an industrial project or a dissertation, which carries a total of 400 marks.

3 Evaluation of Summer Internship, Dissertation and Industry Project

3.1 Summer Internship:

A student of the first year of M. Tech (QROR) is required do a ten-week long summer internship after the second semester under the supervision of a permanent faculty member of the Indian Statistical Institute. The student is required to submit the name of the supervisor and the name of the organization where internship will be carried out to the Dean of Studies before the end of classes of the second semester.

A student is required to submit the internship report to the Dean of Studies by a deadline to be announced in the Academic Calendar. The entire evaluation process will be organized

by a Committee appointed by the Dean of Studies.

Each internship report should be evaluated by the supervisor and an examiner to be decided by the Committee. The average of the scores awarded by the supervisor and examiner will be the final score of internship report of a student.

3.2 Industry Project:

A student of the second year of M. Tech (QROR) is required to do a six-month long project in the second semester under the supervision of a permanent faculty member of the Indian Statistical Institute. The student is required to submit the name of the supervisor and the name of the organization where project will be carried out to the Dean of Studies before the end of classes of the first semester.

The entire evaluation process of industry project will be organized by a Committee appointed by the Dean of Studies.

Each project should be evaluated by a Committee appointed by the Dean of Studies, which should consist of members as follows:

(i) Chairman (a faculty member of ISI, who is not the supervisor of the student);

(ii) Convener (the supervisor of the student);

(iii) Member (another faculty member of ISI or an external expert).

An interim progress report of the project must be submitted to the supervisor by the end of the third month of the project duration. The final project report approved and signed by the supervisor must be submitted to the Committee one week prior to the presentation date. A student is required to give a seminar on his/her work to defend his/her work. The evaluation of the project will be done by the Committee by a deadline to be announced in the Academic Calendar.

The final evaluation report along with score must be submitted by the Committee to the Dean of Studies after the seminar.

3.3 Dissertation:

A student of the second year of M. Tech (QROR) is required do a six-month long dissertation in the second semester under the supervision of a permanent faculty member of the

Indian Statistical Institute. The student is required to submit the name of the supervisor to the Dean of Studies before the end of classes of the first semester.

The entire evaluation process dissertation will be organized by a Committee appointed by the Dean of Studies.

Each dissertation should be evaluated by a Committee appointed by the Dean of Studies, which should consist of members as follows:

(i) Chairman (a faculty member of ISI, who is not the supervisor of the student);

(ii) Convener (the supervisor of the student);

(iii) Member (another faculty member of ISI or an external expert).

An interim progress report of the dissertation must be submitted to the supervisor by the end of the third month of the duration of the dissertation works. The final dissertation report approved and signed by the supervisor must be submitted to the Committee one week prior to the presentation date. A student is required to give a seminar on his/her work to defend his/her work. The evaluation of the dissertation will be done by the Committee by a deadline to be announced in the Academic Calendar.

The final evaluation report along with score must be submitted by the Committee to the Dean of Studies after the seminar.

********** END **********