

INDIAN STATISTICAL INSTITUTE

Students' Brochure PART II

Master of Science in Quality Management and Business Analytics

(Effective from 2026-27 Academic Year)

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



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INDIAN STATISTICAL INSTITUTE
Master of Science in Quality Management and Business Analytics

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1 Curriculum

This two-year program consists of *14 compulsory courses, 2 elective courses* in the first three semesters, and a dissertation along with a live project in the fourth semester. The first two semesters will be conducted at *Bengaluru campus* while the third semester will take place at the *Hyderabad campus*. The project work in the fourth semester will be carried out at the respective Centre or Unit of ISI where the student is undertaking the project. All courses, except dissertation and project work, are assigned four hours per week. The structure given below follows the sequencing approved in the 86th meeting of the Academic Council.

First Year

Semester I (500 marks)

Statistics for Decision Making I*

Probability

Operations Research I

Quality Management I

Business Analytics I

Foundations of Industrial Engineering*

Semester II (600 marks)

Statistics for Decision Making II

Statistical Quality Control

Reliability

Applied Regression & Time series analysis

Business Analytics II

Elective I

* Statistics for Decision Making I (*For all students except those with statistics degree*)/
Foundations of Industrial Engineering (*Only for students from statistics degree*)

Second Year

Semester I (500 marks)

Multivariate Analysis

Operations Research II

Industrial Experimentation

Quality Management II

Elective II

Semester II (400 marks)

Dissertation (100 marks)

Project/Dissertation (300 marks)

Elective Courses[#]

Elective I

Supply Chain & Operations Management
Foundations of MSME Practices & Management

Elective II

Survival Analysis
Advanced Operations Research

[#]Whether a particular elective course is offered in a given semester will depend on students' interest and availability of teachers.

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

Statistics for Decision Making I

1. Introduction (8)

Definition of Statistics, Descriptive and Inferential Statistics, Basic objectives, Applications to various disciplines with examples, Abuses of statistics, Impact of Computer on Data analysis. Primary and Secondary data, Population and Sample, Representative Sample, Types of data – continuous and discrete, frequency and non-frequency data, variable and attribute, Types of measurement scale, Likert scale.

2. Descriptive Statistics (16)

Scrutiny, classification, and tabulation of univariate data. Data visualization – bar plot, line diagram, column diagram, Histogram, pie chart, Box plot, Multi-vari chart. Descriptive statistics – central tendency, dispersion, quantiles, Skewness and Kurtosis; various properties of these measures and their utility. Bivariate data – definition and real-life examples, marginal and conditional frequency distribution, Scatter diagram, Simple linear regression, correlation, least squares method, Rank correlation.

3. Association of Attributes (8)

Definition of attributes with real life examples, Contingency table, Sensitivity and specificity, Types and measures of association, Odds ratio, Cohen's Kappa.

4. Sampling Techniques (8)

Random sampling, Bias and its sources, Sampling from finite and infinite populations, Estimates and standard error (sampling with replacement and sampling without replacement), Sampling distribution of sample mean, Stratified random sampling, Systematic sampling, Cluster sampling.

5. Fitting probability distribution (6)

Empirical distribution function, Kernel density estimation. Fitting probability distributions to observed data. Goodness of fit using Pearson's χ^2 , and P-P and Q-Q plots.

6. Simulation (4)

Simulation from probability distributions, Monte Carlo simulation.

References

1. Spiegelhalter, D. (2019). *The art of statistics: How to learn from data*. Pelican Books.
2. Holcomb, Z. (1998). *Fundamentals of descriptive statistics*. Routledge, Taylor & Francis Group.
3. Jones, J. S., & Goldring, J. (2022). *Exploratory and descriptive statistics*. Sage Publishers.
4. Montgomery, D. C., & Runger, G. C. (2016). *Applied statistics and probability for engineers (6th ed.)*. Wiley.
5. Mood, A. M., Graybill, F. A., & Boes, D. C. (2017). *Introduction to the theory of statistics (3rd ed.)*. McGraw-Hill Education.
6. Goon, A. M., Gupta, M. K., & Dasgupta, B. (1978). *Fundamentals of statistics (Vols. 1–2)*. World Press.
7. Rencher, A. C., & Christensen, W. F. (2012). *Methods of multivariate analysis*. Wiley.
8. Montgomery, D. C., Peck, E. A., & Vining, G. G. (2012). *Introduction to linear regression analysis (5th ed.)*. Wiley.
9. Thomopoulos, N. T. (2013). *Essentials of Monte Carlo simulation*. Springer.
10. Robert, C. P., & Casella, G. (2004). *Monte Carlo statistical methods*. Springer.

Probability

1. Concept of probability (8)

Concept of random experiment with examples. Sample space and events. Basic properties with union and intersection of events. Classical definition of probability and its drawbacks. Axiomatic definition of probability, conditional probability, Bayes' theorem, Independence of events, pair wise and mutual independence.

2. Concept of random variables and probability distributions (8)

Discrete and continuous random variables, Probability mass function, Probability density function, Cumulative distribution function, Expectation, Variance, Moments, Moment generating function, Probability generating function, etc.

3. Discrete distributions (7)

Binomial, Geometric, Negative Binomial, Poisson; Poisson approximation to Binomial distribution; moments- expectation and variance. Independence of discrete random variables. Distribution of the sum of two or more discrete independent random variables.

4. Continuous distributions (8)

Uniform, Normal, Log-Normal, Exponential, Weibull and their moments; 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.

5. Bivariate distribution (7)

Joint probability distribution; Conditional distributions; covariance; correlation coefficient; bivariate normal distribution.

6. Limit Theorems (3)

Chebyshev's inequality, Weak law of large numbers (WLLN), Central limit theorem (Lindebergh & Levy).

7. Stochastic Process (9)

Concept of Stochastic process, Markov Chains: Definition, Examples - Transition probability matrix - Chapman- Kolmogorov equation - classification of states - limiting and stationary distributions - ergodicity.

References

1. Hoel, P. G., Port, S. C., & Stone, C. J. (1971). *Introduction to probability theory*. Houghton Mifflin.
2. Feller, W. (1957). *An introduction to probability theory and its applications (Vol. 1)*. John Wiley & Sons.
3. Feller, W. (1966). *An introduction to probability theory and its applications (Vol. 2)*. John Wiley & Sons.
4. Ross, S. M. (2005). *A first course in probability*. Prentice Hall.
5. Karlin, S., & Taylor, H. M. (2014). *A first course in stochastic processes*. Academic Press.
6. Medhi, J. (2009). *Stochastic processes (3rd ed.)*. New Age International.
7. Dobrow, R. P. (2016). *Introduction to stochastic processes with R*. Wiley.
8. Cinlar, E. (2013). *Introduction to stochastic processes*. Courier Corporation.

Operations Research I

1. Introduction to Optimization (2)

Origin of Operations Research (OR) and its definitions - Operations Research with special emphasis on interdisciplinary and systems approach, Stages of OR project, problem formulations. Developing a model. Testing the adequacy of the model, Deriving a solution, Evaluation of the solution and implementation. Basic tools for optimization.

2. Linear Programming (18)

Linear programming (LP): examples and modeling. LP formulations using matrix notation, Standard and canonical forms, Row operations, and pivoting. Convex sets, Polyhedral sets, Extreme points and basic feasible solutions, the connection to extreme points. Graphical method for solving LP. Existence of optimal basic feasible solutions. The simplex method. Two-phase and the Big-M method. Degeneracy in LP and its resolution. The revised simplex method and its significance.

3. Duality Theorem (10)

Formulations, The fundamental theorems of duality and proofs, Complementary slackness conditions, The dual simplex algorithm, The sensitivity analysis.

4. Applications of LP (10)

The transportation and the assignment model, the LPP with bounded variables. Case studies on industrial applications of OR and DSS. Game theory: Two-person zero-sum games. Saddle points graphical methods.

5. Advanced techniques in Project Management (10)

PERT/CPM, Sequencing and scheduling, Dependency structure matrix analysis, M7 tools, Decision analysis.

References

1. Ravindran, A. R. (2016). *Operations research and management science handbook*. CRC Press.
2. Hillier, F. S., & Lieberman, G. J. (2015). *Introduction to operations research*. McGraw-Hill Education.
3. Taha, H. A. (2013). *Operations research: An introduction*. Pearson Education India.

Quality Management I

1. Understanding Quality (7)

Quality definitions (Jurans, Taguchi, etc.), Elements of quality, Characteristics of quality (quality of design, quality of conformance, Quality of performance), Dimensions of quality (Kano concepts), Service quality, Stakeholder perceptions (society, customers, management, suppliers). Introduction to evolution of quality: concepts of inspection, quality control, TQM etc.

2. Organizing for Quality (7)

Elements of Strategic Management, Quality policies & objectives, Implementing total quality. Organization for quality, coordination of quality activities, role of upper/middle management, workforce, and teams. Self-managing teams, quality circles.

Culture, Motivation, Creating and maintaining quality awareness; Achieving total commitment to quality.

3. Economics for Quality (7)

Cost of Quality concepts, Costs of Poor Quality (COPQ), Cost of Good Quality (COGP), Categories of Quality Costs, Analysis of Quality Costs, Economic models of quality. Organization bottom line: ROI, NPV, Capital Investment, etc.

4. Approaches for Quality Management (9)

Quality Guru's approaches: Juran, Deming, Feigenbaum, Ishikawa, Taguchi and Crosby, etc. Concepts on Quality Planning, Quality Control, Quality Inspection & Breakthrough, PDCA/PDSA.

5. Tools and Techniques for Quality Management (10)

Overview of 7 QC Tools, M7 tools, Why-Why Analysis, Seven-step approach for problem-solving, Process mapping, Failure Mode & Effect Analysis (FMEA), Fault Tree Analysis (FTA).

6. Systems and Standards for QM & Related Aspects (10)

Overview of quality management system; Basics of ISO 9000/9001/9004, Sector-specific standards, Integrated Management System (IMS), IATF 16949, ISO 14000 systems & other standards; Quality System Audit, Audit Reporting, Accreditation of systems, Overview on quality awards: Deming, National Quality Award, etc.

References

1. Juran, J. M., & Gryna, F. M. (1993). *Quality planning and analysis*. Tata McGraw-Hill.
2. Feigenbaum, A. V. (1991). *Total quality control*. McGraw-Hill.
3. Juran, J. M. (1999). *Juran's quality handbook*. McGraw-Hill.
4. Hall, H. (1990). *Total quality management: A practical approach*. Wiley Eastern.
5. Lock, D. (Ed.). (1993). *Handbook of quality management*. Jaico Publishing House.
6. *International Organization for Standardization*. (2015). ISO 9001, ISO 14001 & IATF 16949 quality assurance system standards. ISO.
7. Ott, E. R., Schilling, E. G., & Neubauer, D. V. (2005). *Process quality control: Troubleshooting and interpretation of data (4th ed.)*. ASQ Quality Press.
8. Society of Manufacturing Engineers. (1988). *Troubleshooting manufacturing processes*. SME, Michigan, USA.
9. Kume, H. (1987). *Statistical methods for quality improvement*. Productivity Press.
10. Ryan, T. P. (2000). *Statistical methods for quality improvement*. John Wiley & Sons.

11. Hart, R. F., & Hart, M. K. (1989). *Quantitative methods for quality and productivity improvement*. ASQ Quality Press.
12. Gitlow, H. S., Oppenheim, A. J., Oppenheim, R. D., & Gitlow, S. J. (1989). *Tools and methods for the improvement of quality*. Irwin Inc.

Business Analytics I

1. Introduction to Analytics (7)

Introduction, reasons for the popularity of business analytics and/or data science, examples of analytics problems, components of an analytics/data science project, important analytics tasks, hypothesis testing, predictive modeling, discovering dimensions, profiling, association, and concurrence grouping, link prediction, constraint optimization, etc.

2. Introduction to R and R Studio (4)

Getting started, installation of R and R Studio, comments, variables, data types, numbers, arithmetic & assignment operators, logical or comparison operators, R math functions, arrays, conditional statements - if, else if, if else, nested if statements, loops - while loop & for loop, R functions, getting help, R packages, vectors, matrix, data frames, importing and exporting data, data summarization, visualization.

3. Introduction to Python (8)

Getting started, installation of Python, Anaconda Navigator, & Jupyter Notebook, variables, comments, data types, Python keywords, arithmetic operators, comparison operators, Python math functions, lists, arrays, array functions, conditional statements - if else, loops - while loop & for loop, Python functions, data frames, importing and exporting data, data summarization & Visualization.

4. Data Preprocessing (6)

Data sorting, filtering, file merging, feature generation, file appending, missing value handling - checking for missing values, identifying fields with missing values, deleting missing value records, missing value imputation techniques, identification of zeros, duplicate records, unique records, etc. in datasets and anomaly detection.

5. Data Visualization using R & Python (6)

Correlation, scatter plot, data aggregation, box plot, interval plot, density plot, conditional density plot, cross tabulation & contingency tables, bar chart, pie chart, mosaic plot.

6. Descriptive Analytics (6)

Summarization of large volumes of data into formats such as tables, charts, graphs, or dashboards, Applications of descriptive analytics - business performance analysis, market research, customer segmentation, inventory management, quality control, logistics & transportation, maintenance & repair, employee performance, etc., descriptive analytics examples in sales and supply chain management.

7. Introduction to Database Management (5)

Relational Database Management System (RDBMS), database tables, MySQL, MySQL statements - Select, where, and, or, not, order by, insert into, update, delete, joins, functions, etc.

8. RFM Analysis & Customer Segmentation (4)

Cosine similarity, collaborative filtering: user-based, item-based, content-based filtering, and hybrid methods.

9. Association and Co-occurrence grouping (4)

Market Basket Analysis - Frequent itemset generation and association rule mining.

References

1. Jones, O., Maillardet, R., & Robinson, A. (2009). *Introduction to scientific programming and simulation using R*. Chapman & Hall/CRC.
2. Matloff, N. (2011). *The art of R programming: A tour of statistical software design*. No Starch Press.
3. Crawley, M. J. (2012). *The R book (2nd ed.)*. John Wiley & Sons.
4. Chambers, J. M. (2008). *Software for data analysis: Programming with R*. Springer.
5. Unpingco, J. (2016). *Python for probability, statistics, and machine learning*. Springer International Publishing.
6. Kumar, A. (2019). *Mastering pandas: A complete guide to pandas, from installation to advanced data analysis techniques*. Packt Publishing Ltd.
7. Lambert, K. A. (2018). *Fundamentals of Python: First programs (2nd ed.)*. Cengage Learning.

8. Haslwanter, T. (2016). *An introduction to statistics with Python: With applications in the life sciences*. Springer International Publishing.
9. James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). *An introduction to statistical learning: With applications in R*. Springer

Foundations of Industrial Engineering

1. Basic Concepts (10)

Definition of process; objectives, need, and elements of industrial engineering. Overview of engineering processes in different sectors such as mechanical, chemical, and pharma process etc. Engineering Specifications with measurements and units with different examples.

2. Work System Design (12)

Definition of Productivity, Productivity concepts, Manual work systems, Worker-machine systems, Automated work systems, Cycle time analysis of Manual work and in worker machine systems (including numerical), Service operations, Office work, ILO recommendations for productivity measurement of semi & fully automated systems.

Human aspects in Engineering process: Definition, objective, and scope of work study. Work study and management, work-study and supervision, work study and worker.

3. Methods for Work Performance Measurements (20)

Methods and Process Analysis: Basic overview, Techniques of methods engineering, Basic data collection and analysis techniques - Network diagrams, Traditional charting and Diagramming techniques, Block diagrams and Process maps.

Motion study and Work design: Basic motion elements and work analysis, Principles of motion economy and work design.

Work measurement & time study: Work measurement & its techniques, Time study: procedure, Determination of number of work cycle to be timed, Performance rating, time study equipment, Overview of PMTS, MTM, and MOST techniques. Case examples and exercises.

4. Process & Product Quality Understanding and Improvement: (8)

Quality problems & their types, Problem solving approach from the quality viewpoint: mindset, quality first, consumer orientation; PDCA cycle, Process control, dispersion control, recurrence prevention, standardization; Benefits of problem-solving approaches. Case examples and exercises.

References

1. Groover, M. P. (2017). *Work systems: The methods, measurement, and management of work*. Pearson India Education.
2. Kanawayt, G. (1992). *Introduction to work study (4th rev. ed.)*. International Labour Office
3. Meyers, F. E., & Stewart, J. R. (2002). *Motion and time study for lean manufacturing (3rd ed.)*. Prentice Hall.
4. Niebel, B. W., & Freivalds, A. (2014). *Niebel's methods, standards, and work design (13th ed.)*. McGraw-Hill Education.
5. Ott, E. R., Schilling, E. G., & Neubauer, D. V. (2005). *Process quality control: Troubleshooting and interpretation of data (4th ed.)*. ASQ Quality Press.
6. *Society of Manufacturing Engineers*. (1988). *Troubleshooting manufacturing processes*. SME, Michigan, USA.
7. Kume, H. (1987). *Statistical methods for quality improvement*. Productivity Press.
8. Ryan, T. P. (2000). *Statistical methods for quality improvement*. John Wiley & Sons.
9. Hart, R. F., & Hart, M. K. (1989). *Quantitative methods for quality and productivity improvement*. ASQ Quality Press.
10. Gitlow, H. S., Oppenheim, A. J., Oppenheim, R. D., & Gitlow, S. J. (1989). *Tools and methods for the improvement of quality*. Irwin Inc.
11. Chase, R. B., Jacobs, F. R., & Aquilano, N. J. (2006). *Operations management for competitive advantage*. McGraw-Hill/Irwin.

2.2 Second Semester Courses

Statistics for Decision Making II

1. Introduction (2)

Principles of statistical inference. Formulation of the problems with examples.

2. Estimation (12)

Point estimation, Estimator and Estimate, Criteria for good estimates: Unbiasedness, Consistency, Efficiency and Sufficiency with illustrations. Methods of estimation of Parameters of standard distributions. Interval estimation: Confidence intervals of the parameters of the standard distributions.

3. Test of hypothesis (14)

Formulation of the problem and concepts for evaluation of tests, Illustrations. Statistic, Sampling distributions of statistic and its Standard error. Large sample tests in one and two-sample problems of standard probability distributions. Relationship of confidence intervals with tests of hypothesis. Determination of sample size. Analysis of categorical data. Chi squared test for goodness of fit, contingency tables, χ^2 - test for independence and homogeneity.

4. Linear Statistical Models (10)

Definition of linear model, interactions with illustrations. Gauss-Markov Theorem, Generalized linear models. One way and two-way analysis of variance - fixed, random and mixed effect models. Nested ANOVA.

5. Non-parametric Inference (12)

Comparison with parametric inference, Use of order statistics. Run test, Sign test, Wilcoxon signed rank test, Mann-Whitney test, Kolmogorov-Smirnov test. Spearman and Kendall's test, Kruskal-Wallis test.

References

1. Casella, G., & Berger, R. L. (2024). *Statistical inference (2nd ed.)*. CRC Press.
2. Rohatgi, V. K., & Saleh, A. K. Md. E. (2015). *An introduction to probability and statistics (3rd ed.)*. Wiley.
3. Rao, C. R. (2002). *Linear statistical inference and its applications (2nd ed.)*. Wiley.

4. Lehmann, E. L., & Romano, J. P. (2005). *Testing statistical hypotheses (3rd ed.)*. Springer.
5. Lehmann, E. L., & Casella, G. (1998). *Theory of point estimation (2nd ed.)*. Springer.
6. McCullagh, P., & Nelder, J. A. (1989). *Generalized linear models (2nd ed.)*. Chapman & Hall/CRC.
7. Dunn, P. K., & Smyth, G. K. (2018). *Generalized linear models with examples*. Springer.
8. Dobson, A. J., & Barnett, A. G. (2008). *An introduction to generalized linear models*. Chapman & Hall/CRC.
9. Tsybakov, A. B. (2009). *Introduction to nonparametric estimation*. Springer.
10. Gibbons, J. D., & Chakraborti, S. (2020). *Nonparametric statistical inference (6th ed.)*. CRC Press.

Statistical Quality Control

1. Introduction to SPC (2)

Concept of process, Role of SPC in this context, Concept of variation due to common and assignable causes; meaning of control, expected benefits of SPC.

2. Control Charts (18)

- Introduction to Shewhart Control charts, Statistical basis for control charts, Control chart for variables and attributes: \bar{X} -R; \bar{X} -S; \bar{X} -MR; p, np, c, u charts.
- Sloping control chart, modified control limits, CUSUM chart, EWMA chart, Pre-control chart, Run Chart.
- Group control chart for multiple stream processes.
- Control chart for short run processes.
- Dominance System – Concept of Process dominance patterns (setup, machine, operator, component, etc.) with examples, and methods of process control.
- Implementation of Process Control – Steps for implementation of control chart for on line process monitoring with out-of-control action plan.

3. Process Capability Analysis (6)

Process capability Analysis, process capability and machine capability indices (C_p , P_p , C_{pk} , P_{pk} , C_{pm} , C_{pmk}), Process Capability calculation for Non-normal data, Clements' method.

Estimation of process capability indices for live data by statistical software.

Approaches for process improvement an overview.

4. Engineering process control (EPC) & Taguchi's Online QC Technique (6)

Process Monitoring, Process regulation, Process control by Feedback adjustment, Combining EPC & SPC. Taguchi's Loss Function and quality level – definition and calculation of loss function for different types of quality characteristics. Online quality control system and method of process improvement – calculation of Beta correction factor by ANOVA method and implementation of the same.

5. Acceptance Sampling (18)

Purpose of sampling inspection, Critique of acceptance sampling, Relevance of sampling inspection in today's techno-economic scenario.

Concept and definitions: Single sampling, Double sampling, Multiple sampling plans, AQL, LTPD, Type A and Type B OC function, ASN, AOQL and ATI for acceptance rectification plans.

Published sampling plans: Dodge-Romig system of AOQL and LTPD plans; Sampling plans based on OC curve; Military standards (105D, 105E, 1414) and equivalent Indian/ISO standards.

Continuous sampling plans (CSP-1, CSP-2, CSP-3, etc.), Multilevel plans.

Special purpose plans: Chain sampling, Sequential sampling plan, Skip lot sampling plans.

References

1. Montgomery, D. C. (2019). *Introduction to statistical quality control (8th ed.)*. Wiley.
2. Grant, E. L., & Leavenworth, R. S. (2017). *Statistical quality control (7th ed.)*. McGraw-Hill.
3. Duncan, A. J. (1974). *Quality control and industrial statistics (5th ed.)*. Irwin.

4. Schrock, E. M. (2013). *Quality control and statistical methods*. Asia Publishing House.
5. Wetherill, G. B., & Brown, D. W. (1991). *Statistical process control: Theory and practice*. Chapman & Hall.
6. Dodge, H. F., & Romig, H. G. (1941). *Single sampling and double sampling inspection tables*. Bell System Technical Journal, 20, 1–61. (Reprinted in Dodge, H. F., & Romig, H. G. (1959). *Sampling inspection tables* (2nd ed.). Wiley.)
7. U.S. Department of Défense. (1963). *Sampling procedures and tables for inspection by attributes (MIL-STD-105D)*. U.S. Government Printing Office.
8. Johnson, S., & Kotz, S. (Eds.). (2016). *Multivariate QC*. In *Encyclopaedia of statistical sciences* (Vol. 6). Wiley.
9. Banks, J. (1989). *Principles of quality control*. John Wiley & Sons.
10. Pearn, W. L., & Kotz, S. (2016). *Encyclopaedia and handbook of process capability indices: A comprehensive exposition of quality control measures (Series on Quality, Reliability and Engineering Statistics, Vol. 12)*. World Scientific Publishing.

Reliability

1. Introduction (2)

Definition of reliability and related measures; concept of failure; quality and reliability; importance of reliability.

2. Failure Patterns – Probability Models (8)

Hazard rate; bath tub curve; causes of early failure; failure-time distributions: Exponential, Weibull, Log-normal, Gamma; their properties and uses.

3. System Reliability (10)

Series, parallel, series-parallel, r-out-of-n configurations; reliability block diagram; cut set and path set; reliability of different system.

4. Life Testing (12)

Life testing methods; estimation of parameters and reliability with standard probability models using complete and censored samples; Type - I, Type – II, Interval, random and progressive censoring. Properties of these estimators; confidence intervals;

probability plot and graphical procedures for estimating the parameter; validation of model; life test acceptance sampling plans in exponential case.

5. Reliability of Repairable System (12)

Types of repair: good-as-new, minimal; modeling failure processes: renewal process, Poisson process, non-homogeneous Poisson process. Serviceability, maintainability, availability, operational readiness; reliability and maintainability trade-off.

6. Warranty Analysis (6)

Role of warranty; quality improvement versus warranty; free-replacement warranty (FRW) and pro-rated warranty (PRW); warranty policy and cost; analysis of warranty policy – some simple cases.

References

1. Kapur, K. C., & Lamberson, L. R. (1977). *Reliability in engineering design*. John Wiley & Sons.
2. Meeker, W. Q., & Escobar, L. A. (1998). *Statistical methods for reliability data*. John Wiley & Sons.
3. Lawless, J. F. (1982). *Statistical models and methods for lifetime data*. John Wiley & Sons.
4. Ascher, H., & Feingold, H. (1984). *Repairable system reliability*. Marcel Dekker.
5. Blischke, W. R., & Murthy, D. N. P. (1994). *Warranty cost analysis*. Marcel Dekker.
6. Srinath, L. S. (1975). *Concepts in reliability*. Affiliated East-West Press Pvt. Ltd.
7. Barlow, R. E., & Proschan, F. (1975). *Statistical theory of reliability and life testing*. Holt, Rinehart and Winston.

Applied Regression & Time Series Analysis

1. Simple Linear Regression (5)

The simple regression model, importance of scatter plot, Least squares method of estimation of parameters, Test for slope and intercept, Interval estimation in simple linear regression, Prediction of new observations, Co-efficient of determination, Estimation by maximum likelihood method.

2. Checking Model Adequacy (5)

Residual analysis, Detection and treatment of outliers, Lack of fit and pure error, Need for transformation, Weighted least squares. Autocorrelation.

3. Multiple Linear Regression (20)

Multiple regression models, Estimation of model parameters, Confidence intervals and hypothesis testing in multiple regression, Prediction of new observations, Multiple correlation co-efficient. Polynomial regression. Checking for the validity of model assumptions: Role of residuals and hat matrix, standardized and studentized residuals. Plots: Fitted values against residuals, regressors against residuals, added variable plots, normal probability plot.

Detecting influential observations: DFBETAS, DFFITS, Cook's D, COVRATIO.

Sources and effects of multicollinearity, multicollinearity diagnostics: VIF and variance proportions.

Methods for dealing with multicollinearity, Principal component regression and its pitfalls, Subset selection: Criteria for choice of subset size, Co-efficient of multiple determination, Residual mean square, Adjusted co-efficient of determination, Mallows' Cp statistic, AIC and BIC criteria. Comparison of different criteria. Ridge regression. Validation of regression models.

4. Indicator Variables (3)

Concept and use of indicator variables as regressors, models with only indicator variables, interaction terms involving indicator variables, indicator variables for segmented models.

5. Terminologies in the use of Regression analysis (5)

Heteroscedasticity, Transformations, Box-Cox transformation, Generalized least squares, Designed experiments for regression, Relationship between regression and analysis of variance. Non-linear models: Estimation of parameters of a non-linear system.

6. Logistic Regression (4)

Discrete response models, Linear probability models, Logistic regression model, Test of significance of coefficients, Multiple logistic regression model, Fitting and testing the significance of the model, Interpretation of the coefficients of the logistic regression model – Dichotomous, Polytomous and Continuous independent variable, Measures of goodness of fit – Pearson Chi-square and Deviance, Hosmer–Lameshow tests, Logistic regression diagnostics. Probit regression

7. Time Series and Forecasting (8)

Introduction to time series and forecasting, Nature of time series data, Measures of Dependence: Auto Correlation and Cross Correlation, ACF & PACF, Portmanteau Tests, Dicky Fuller (DF) & ADF tests, Stationarity and Non-stationarity, Tests of stationarity, Additive & Multiplicative models, Exponential and Double Exponential Smoothing, ARMA, ARIMA models, Introduction to Vector ARIMA, ARCH and GARCH models.

References

1. Draper, N. R., & Smith, H. (1998). *Applied regression analysis*. McGraw-Hill.
2. Rawlings, J. O., Pantula, S. G., & Dickey, D. A. (1998). *Applied regression analysis: A research tool*. Springer.
3. Montgomery, D. C., Peck, E. A., & Vining, G. G. (2021). *Introduction to linear regression analysis*. John Wiley & Sons.
4. Chatterjee, S., & Hadi, A. S. (2015). *Regression analysis by example*. John Wiley & Sons.
5. Dobson, A. J., & Barnett, A. G. (2018). *An introduction to generalized linear models*. Chapman & Hall/CRC.
6. Hosmer, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). *Applied logistic regression (3rd ed.)*. Wiley.

Business Analytics II

1. Introduction to Data Analytics (10)

Introduction to types of data. Basic operations including convolution, correlation, and filtering of signal/image/video information. Basic transformation methods.

Basics of pattern recognition. Design principles of pattern recognition system. Learning and adaptation.

2. Feature Selection and Extraction (8)

Feature selection problem statement and uses. Probabilistic Separability-based criterion functions. Interclass distance-based criterion functions. Branch and bound algorithm. Sequential forward/backward selection algorithms. Feature extraction approaches: PCA, Kernel PCA, Transform-based methods.

3. Supervised Learning (10)

Standardization and normalization. Linear and non-linear discriminant boundaries. Bayesian Decision Theory. Distance metrics. Basic classification methods, such as minimum distance, K-NN Classifiers, etc. Linear and Logistic Regression. Cost function optimization. Classification & Regression Tree (CART). Ensemble classification methods - bagging, random forest, boosting & voting classifier.

4. Performance evaluation and model comparison (8)

Choosing the right model: accuracy vs speed vs interpretability. Metrics for supervised learning performance evaluation, types of errors, ROC curves, and confusion matrices and related measures. Metrics for unsupervised learning performance evaluation. Cross-validation methods, Training sets and test sets, leave one out, k-fold, stratified. Bias-Variance trade off.

5. Unsupervised Learning (8)

Minimum within cluster distance criterion. K-means clustering. Single linkage and complete linkage clustering, MST, DBSCAN, etc.

6. Application of Pattern Recognition Model (6)

Face Detection, Sentiment Analyzer, Object Detection, Fraud Analytics, Real time Analytics. A/B Testing.

References

1. Duda, R. O., Hart, P. E., & Stork, D. G. (2001). *Pattern classification (2nd ed.)*. Wiley.
2. Bishop, C. M. (1995). *Neural networks for pattern recognition*. Oxford University Press.
3. Haykin, S. (2009). *Neural networks and learning machines (3rd ed.)*. Pearson Education India.
4. Theodoridis, S., Koutroumbas, K., & Tsoumakas, G. (2010). *Introduction to pattern recognition: A MATLAB approach*. Academic Press.
5. Géron, A. (2022). *Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow*. O'Reilly Media.

6. Hastie, T., Tibshirani, R., & Friedman, J. (2009). *The elements of statistical learning: Data mining, inference, and prediction (2nd ed.)*. Springer.
7. Starmer, J. (2022). *The StatQuest illustrated guide to machine learning*. StatQuest.
8. Mello, R. F., & Ponti, M. A. (2018). *Machine learning: A practical approach on the statistical learning theory*. Springer.
9. James, G., Witten, D., Hastie, T., and R. Tibshirani. (2021), *An Introduction to Statistical Learning: with Applications in R*. Springer,
10. Mehryar, M., Rostamizadeh, A. and Talwalkar, A. (2018). *Foundations of Machine Learning*. MIT Press.

Elective I

Supply chain & Operations Management

1. Supply Chain Management: Introduction & Philosophy (8)

Concepts on Supply Chain, Supply chain networks, Integrated supply chain planning, process view (mapping and flow chart) of a supply chain, and supply chain flows. Overview of supply chain models and modelling systems, Supply chain planning, Supply Chain Management as a Management Philosophy, Function of Supply Chain Management, Customer focus in Supply Chain Management, Buyers and Suppliers Perspective, Value chain. Introduction to distribution network, Factors influencing distribution, design options, e-business, and its impact.
2. Supply Chain Network Design (5)

Supply chain distribution networks in Practice, network design in the supply chain, modelling for supply chain. Transportation network and sourcing in supply chain.
3. Planning Supply and Demand (8)

Role of Forecasting in a supply chain, Factors of Demand Forecast, Basic approach to Demand Forecasting, Aggregate planning in supply chain, Managing Predictable variability.
4. Operations Management (7)

Introduction; Historical Development, Concept of Production, Classification of Production System, Production Management, A Framework of Managing Operations, Operations Management, Productivity, and productivity analysis.

5. Aggregate Planning and Scheduling (7)

Introduction to Aggregate Production Planning, Variables used in Aggregate Planning, Aggregate Planning Strategies, Mixed Strategies, Mathematical Planning Model, Master Scheduling. Introduction to Scheduling, Classification of Scheduling Problems (Sequence of Machines, Number of Machines, Job Arrival Times, etc), Two Machines Flow-Shop Problem, Single-Machine Scheduling.

6. Project Management (8)

Introduction; Critical path method; PERT network analysis; Statistical analysis of project duration; Precedence diagramming method; Software tools for project management.

7. Simulation (7)

Introduction; Basics of simulation; Simulation languages and software; Simulation projects.

References

1. Hillier, F. S., & Lieberman, G. J. (2015). *Introduction to operations research*. McGraw-Hill.
2. Chopra, S., Meindl, P., & Kalra, D. V. (2007). *Supply chain management*. Pearson Education India.
3. Chopra, S., & Meindl, P. (2016). *Supply chain management: Strategy, planning, and operation (6th ed.)*. Pearson Education.
4. Raghuram, G., & Rangaraj, N. (2000). *Logistics and supply chain management: Cases and concepts*. Macmillan India Ltd.
5. Simchi-Levi, D., Kaminsky, P., & Simchi-Levi, E. (1999). *Designing and managing the supply chain: Concepts, strategies, and cases*. McGraw-Hill.
6. Handfield, R. B., & Nichols, E. L., Jr. (1999). *Introduction to Supply chain management*. Prentice Hall.
7. Mentzer, J. T., Myers, M. B., & Stank, T. P. (2006). *Handbook of global supply chain management*. Sage Publications.
8. Coyle, J. J., Bardi, E. J., & Langley, C. J. (1992). *The management of business logistics (Vol. 580)*. West Publishing Company.

9. Ballon, R. H. (2004). *Business logistics/supply chain management: Planning, organizing, and controlling the supply chain*. Pearson Education, Inc.
10. Pandey, R. (2001). *Essentials of supply chain management* (R. P. Mohanty & S. G. Deshmukh, Authors). 238–239.

Foundations of MSME Practices & Management

1. Introduction (2)

About Micro Small and Medium Entrepreneurship (MSME): Concept & Definition; Role of Business in the modern Indian Economy SMEs in India; Employment and export opportunities in MSMEs; Issues and challenges of MSMEs.

2. Statistical Methods in MSMEs (15)

Fundamental of Statistical Methods & Techniques in MSMEs; Sampling; Data Collection methods; Probability Distribution; Data Analysis; SPC – Control charts (variable and attributes charts), Process Capability, Acceptance Sampling, Product & Process Design – Experimental Designs; Reliability Engineering; Methods for Process Modeling. Case examples and exercises.

3. Shop Floor Practices in MSMEs (15)

Quality Management: Brief introduction about quality management in MSMEs; MSMEs Classification; Importance of Quality Management in Business Processes; Management Practices. Quality Management Tools: Six Sigma; Seven Quality Control Tools; Measurement System Analysis: Gauge R &R; QFD: Vendor rating and Value Analysis.

Lean Concepts & Tools: 5S –Value stream mapping – Changeover/setup time (SMED); Production leveling – Line balancing; TPM (Objectives and functions) – Reliability Centered Maintenance (RCM) – maintenance types; Outsourcing – Make vs. buy approach.

Case examples and exercises on Six Sigma in MSMEs.

4. Research and Development Practices in MSMEs (10)

Overview on creativity & innovation; ICEDIP Process and Tools – Six Thinking Hats, Lateral Thinking, TRIZ methodology, 8D approach etc., Pilot to Production, Project Evaluation Methods, Case examples.

5. Quality and Excellence in MSMEs (6)

Institutional (MSME): Overview on Quality systems – Basics of ISO 9000/9001/9004, Sector-specific standards, & other standards; Requirements and benefits – awards for MSMEs like EFQM excellence model; Malcolm Baldrige quality award; Deming’s Prize; Rajiv Gandhi National Quality Award (RGNQA)- IMEA Award; IEI Industry Excellence award etc.

Individual (MSME Employee): Overview on Self certifications & benefits; ASQ certifications – Six Sigma belts; CRE; CSQP, CSQE; Program Management Professional (PgMP); Certified Associate in Project Management (CAPM); Quality Auditor.

6. Setting of MSMEs (2)

Overview on setting up of MSMEs; Different schemes & formalities for setting up an enterprise; Location of Enterprise; Rural entrepreneurship – Women entrepreneurship.

References

1. Chaudhury, S. K. (2013). *Micro, small and medium enterprises in India*. Raj Publications.
2. Aneet, & Agarwal, M. (2009). *Small and medium enterprises in transitional economies: Challenges and opportunities*. DEEP and DEEP Publications. <https://doi.org/ISBN:978-8184501667>
3. Shukla, M. B. (2011). *Entrepreneurship and small business management*. Kitab Mahal.
4. Sharma, R. K. (n.d.). *Quality management practices in MSME sectors*. Springer Singapore. <https://doi.org/ISBN:978-981-15-9511-0>
5. Antony, J., Vinodh, S., & Gijo, E. V. (2016). *Lean Six Sigma for small and medium-sized enterprises: A practical guide*. CRC Press.
6. Chase, R. B., Jacobs, F. R., & Aquilano, N. J. (2006). *Operations management for competitive advantage*. McGraw-Hill/Irwin.
7. Montgomery, D. C. (2019). *Introduction to statistical quality control (8th ed.)*. Wiley.
8. Kume, H. (1987). *Statistical methods for quality improvement*. Productivity Press.

9. Ryan, T. P. (2000). *Statistical methods for quality improvement (2nd ed.)*. John Wiley & Sons.
10. Hart, R. F., & Hart, M. K. (1989). *Quantitative methods for quality and productivity improvement*. ASQ Quality Press.
11. Lesikar, R. V., Pettit, J. D., & Flatly, M. E. (2009). *Lesikar's basic business communication (11th ed.)*. Tata McGraw-Hill.
12. Hurr, F. (1999). *Rousing creativity: Think new now*. Crisp Publications Inc. ISBN 1560525479.

2.3 Third Semester Courses

Multivariate Analysis

1. Multivariate data (3)

Introduction to Multivariate data, Multivariate data visualization, Multivariate data summarisation.

2. Multivariate normal distribution (18)

Multivariate normal distribution and its properties, Inference on mean vectors in multivariate populations, Hotelling's T^2 : Comparing Mean Vectors from Two Populations, Wishart distribution (definition, properties); Construction of tests using Union - Intersection and likelihood ratio principles, Mahalanobis D^2 , Bartlett's Test, MANOVA.

3. Principal Component Analysis (5)

Principal Component Analysis (PCA) based on the population covariance matrix, analysis based on the sample covariance matrix; use of principal components.

4. Factor analysis (5)

Loading, communality, variance of a factor & total variance; estimation of Parameters, choosing number of factors; selection of loading - rotation.

5. Discriminant Analysis and Classification (7)

Concepts of discriminant analysis - Computation of linear discriminant function (LDF) - Classification between k multivariate normal populations based on LDF - Fisher's Method for discriminating two or several populations - Evaluating Classification Functions - Probabilities of misclassification and their estimation - Mahalanobis D^2 .

6. Cluster analysis, Multidimensional scaling, Correspondence analysis (8)

Similarity measures, clustering methods and algorithms; multidimensional scaling – basic algorithm; correspondence analysis – algebraic development, inertia, interpretation.

7. Methods for multivariate SPC (4)

Multivariate control charts, Multivariate process capability analysis.

References

1. Johnson, D. E. (1998). *Applied multivariate methods for data analysts*. Duxbury Press.
2. Hair, J. F., Jr., Anderson, R. E., Tatham, R. L., & Black, W. C. (2006). *Multivariate data analysis with readings (6th ed.)*. Pearson Prentice Hall.
3. Sharma, S. (1996). *Applied multivariate techniques*. Wiley.
4. Mason, R. L., & Young, J. C. (2002). *Multivariate statistical process control with industrial applications*. Society for Industrial and Applied Mathematics.
5. Malhotra, N. K., Nunan, D., & Birks, D. F. (2020). *Marketing research (5th ed.)*. Pearson UK.

Operations Research II

1. Integer Programming (10)

Introduction to ILP, formulation, branch and bound and cutting plane methods for solving ILPs. Applications of ILP: traveling salesman problem, cutting stock, and material optimization problems. The minimum cost network flow problems, Network Models.

2. Dynamic Programming (8)

Deterministic dynamic programming problems, Bellman's optimality principle, Forward and backward approaches for solving dynamic programming problems, and continuous and discrete variable problems.

3. Queueing Models (7)

Introduction to waiting line models, steady-state behaviour of M/M/1, M/M/C queues, the problem of machine interference problem and use of finite queueing tables, introduction to M/G/1 and M/G/C models.

4. Inventory Control & Management (10)

Introduction to Supply Chain Inventory Management - cycle and safety inventory. Inventory theory: Economic Order Quantity Models, Reorder Point Models and Multi-echelon Inventory Systems, Relevant deterministic and stochastic inventory models, Single and multi-product, Inventory management in practice (JIT, VMI, etc.).

5. Non-Linear Programming (15)

Unconstrained optimization problem and the optimality conditions (steepest descent method, and conjugate direction method). The constrained nonlinear optimization problem; Lagrange multiplier method, Karush-Kuhn-Tucker optimality conditions; necessary and sufficient conditions for optimality.

References

1. Bazaraa, M. S., Sherali, H. D., & Shetty, C. M. (2006). *Nonlinear programming: Theory and algorithms (3rd ed.)*. John Wiley & Sons.
2. Boyd, S., & Vandenberghe, L. (2004). *Convex optimization*. Cambridge University Press.
3. Pardalos, P. M., & Resende, M. G. C. (2002). *Handbook of applied optimization*. Oxford University Press.
4. Taha, H. A. (2013). *Operations research: An introduction (9th ed.)*. Pearson Education India.
5. Luenberger, D. G. (1997). *Optimization by vector space methods (2nd ed.)*. John Wiley & Sons.

Industrial Experimentation

1. Introduction (2)

Introduction to Design of Experiments, Role of experimental designs in industries, Identification, and classification of factors. Classical statistical design of experiments, Basic principles of experimentation, concept of main effect and interaction, Current trends in experimentation.

2. Basic Designs (4)

Completely Randomized Design, Randomized complete block design, Latin square design, Residual analysis: assessment of Model.

3. Factorial Designs (14)

Introduction to factorial design, 2^K and 3^K factorial designs, Statistical analysis, Model adequacy checking. Confounding in the 2^K factorial design. 2^{k-p} and 3^{k-p} fractional Factorial designs. Residual analysis: model adequacy tests.

4. Nested/Hierarchical Designs (4)

Two-stage nested design, Statistical analysis, diagnostic checking. General m-stage nested designs. Design with nested and crossed factors.

5. Response Surface Methodology (5)

Introduction, Method of steepest ascent, Analysis of quadratic models, Response surface designs for first order and second order models, rotatable and orthogonal designs, Equiradial, simplex, central composite, Box Behnken designs, Optimal design and criteria.

6. Mixture Designs (5)

Introduction, Simplex lattice designs (Scheffe). Simplex centroid designs, Extreme vertices designs, Response surface designs with mixtures: first order and second order model for constrained mixture spaces.

7. Taguchi Methods (Phase I) (5)

Linear graphs and their applications, Different types of Orthogonal Arrays, Split unit design, Multilevel arrangement, Pseudo-factor designs, Statistical analysis.

8. Taguchi's Robust Designs (Phase II & III) (7)

Taguchi's philosophy of quality engineering, Loss function, Taguchi's Noise strategy contrasting basic principles of classical experimentation. Concepts of robust design (parameter design & tolerance design), Inner array and outer array, Signal to noise ratios - static and dynamic, Statistical analysis, Critique of Taguchi Methods.

9. Computer-Aided Experiments, Space-Filling Designs (4)

Overview on computer-aided experiments, Space filling designs.

References

1. Montgomery, D. C. (2019). *Design and analysis of experiments (10th ed.)*. John Wiley & Sons.

2. Box, G. E. P., & Hunter, W. G. (1978). *Statistics for experimenters: An introduction to data analysis and model building*. John Wiley & Sons.
3. Cochran, W. G., & Cox, G. M. (1992). *Experimental designs (2nd ed.)*. John Wiley & Sons.
4. Fisher, R. A. (1974). *The design of experiments*. Hafner.
5. Ghosh, S. (1990). *Statistical design and analysis of industrial experiments*. Marcel Dekker.
6. Das, M. N., & Giri, N. C. (1981). *Design and analysis of experiments*. Wiley Eastern.
7. Box, G. E. P., & Draper, N. R. (1987). *Empirical model building and response surfaces*. John Wiley & Sons.
8. Myers, R. H., & Montgomery, D. C. (2016). *Response surface methodology: Process and product optimization using designed experiments (4th ed.)*.
9. Khuri, A. I., & Cornell, J. A. (1996). *Response surface designs and analysis*. Marcel Dekker.
10. Taguchi, G. (1986). *Introduction to quality engineering*. APO, UNIPUB.
11. Taguchi, G. (2016). *Introduction to off-line quality control*. Central Japan Quality Control Association.
12. Taguchi, G. (1987). *System of experimental designs: Engineering methods to optimize quality and minimize cost*. UNIPUB/Kraus International.
13. Cornell, J. A. (2006). *Experiments with mixtures: Design, model, and the analysis of mixture data*. John Wiley & Sons.
14. Wu, C. F. J., & Hamada, M. (2000). *Experiments: Planning, analysis, and parameter design optimization*. John Wiley & Sons.
15. Taguchi, G., & Chowdhury, S. (2004). *Taguchi's quality engineering handbook (Y. Wu, Ed.)*. John Wiley & Sons.

Quality Management II

1. Six Sigma Methodology (5)

Introduction to Six Sigma, Principles of Six Sigma – DMAIC & DFSS Philosophy, Six Sigma Implementation Process – How to Select Six Sigma Project, Role of Top Management; Role of - Champion, Master Black Belt, Black Belt, Green Belt & Yellow Belt; Training strategy.

2. DMAIC Methodology (20)

VOC, QFD, CTQ, CTQ Tree, Project Charter, SIPOC, Process Map, Cause & Effect Matrix, MSA: variable & attribute - R& R Concepts, Estimation of Kappa, Uncertainty Measurement etc., performance evaluation, Benchmarking, Tools for Analyze, Improve, and Control phase. EFQM Business Excellence Models.

3. Lean Concepts and Methodology (15)

Definition of waste and its types, Value-added (VA) and non-value-added activities (NVA), Takt Time, Flow, pull & Bottleneck, Value stream Mapping, Cycle time Determination, Lean Tools: 5S, Kaizen, Kanban, GEMBA, SMED, poka-yoke etc. Overview of Risk Analysis & Mitigation Methods. Introduction to Toyota Production System: Philosophy and Objectives.

4. Sustainable Quality Management (10)

Integration of Lean Six Sigma Methodology with a focus on the environment & society.

References

1. Przekop, P. (2005). *Six Sigma for business excellence*. McGraw-Hill.
2. Brue, G., & Launsby, R. (2003). *Design for Six Sigma*. McGraw-Hill.
3. Cavanagh, R., Neuman, R., & Pande, P. (2005). *What is design for Six Sigma*. Tata McGraw-Hill.
4. Pande, P. S., Neuman, R. P., & Cavanagh, R. R. (2000). *The Six Sigma way: How GE, Motorola, and other top companies are honing their performance*. McGraw-Hill.
5. George, M., Rowlands, D., & Kastle, B. (2004). *What is Lean Six Sigma*. McGraw-Hill.
6. Montgomery, D. C. (n.d.). *Introduction to statistical quality control (5th ed.)*. Wiley.

7. Gupta, P. (2004). *Six Sigma business scorecard*. McGraw-Hill.
8. Adams, C. W., Wilson, C. E., Jr., & Gupta, P. (2003). *Six Sigma deployment*. Elsevier Science.
9. Munro, R. A., Ramu, G., & Zrymiak, D. J. (2022). *Certified Six Sigma Green Belt handbook (3rd ed.)*. ASQ.
10. McShane-Vaughn, M. (2022). *Certified Six Sigma Black Belt handbook (4th ed.)*. ASQ.
11. Antony, J., Vinodh, S., & Gijo, E. V. (2016). *Lean Six Sigma for small and medium-sized enterprises: A practical guide*. CRC Press.
12. Bass, I., & Lawton, B. (2009). *Lean Six Sigma using SigmaXL and Minitab*. McGraw-Hill.
13. Voehl, F., Harrington, H. J., Mignosa, C., & Charron, R. (2014). *The Lean Six Sigma Black Belt handbook: Tools and methods for process acceleration*. CRC Press.
14. Turner, J., & Nelly, B. L. (2019). *Lean Six Sigma*. International Consulting Ltd.
15. Creveling, C. M., Slutsky, J. L., & Antis, D., Jr. (2003). *Design for Six Sigma in technology and product development (3rd ed.)*. Pearson Education.

Elective II

Survival Analysis

1. Introduction (2)

Type of data (uncensored, censored, grouped, truncated); Dependence on covariates; Different end points.

2. Failure time models (4)

Exponential, Weibull, and Gamma. Discrete hazard.

3. Likelihood based inference for censored data (8)

Construction of likelihood for different types of censoring; Maximum likelihood estimation (Newton-Raphson method, EM algorithm); Asymptotic likelihood theory (statement of results only); Testing of hypotheses in parametric models.

4. Nonparametric inference (8)

Life Table estimates; Kaplan-Meier estimate; Nelson-Aalen estimate; Two-sample problem.

5. Regression models (5)

Exponential and Weibull regression; Proportional Hazard and Accelerated Life Time models; Discrete regression models; Two-sample problem using regression models.

6. Proportional Hazard model (8)

Marginal and Partial likelihoods; Estimation of baseline survival function; Inclusion of strata; Time dependent covariates; Scope and validity of the PH model.

7. Accelerated Life Time model (5)

Maximum likelihood estimation; Least square estimation; Linear rank test.

8. Competing risks (10)

Cause specific hazard/Multiple decrement models; PH model for competing risks data; Multiple failure time data. Counting Process Theory; Multiplicative intensity model; Nelson-Aalen Estimator.

References

1. Kalbfleisch, J. D., & Prentice, R. L. (2002). *The statistical analysis of failure time data (2nd ed.)*. Wiley.
2. Miller, R. G., Jr. (2011). *Survival analysis*. Wiley.
3. Cox, D. R., & Oakes, D. (1984). *Analysis of survival data*. Chapman & Hall.
4. Lawless, J. F. (2003). *Statistical models and methods for lifetime data (2nd ed.)*. Wiley.
5. Klein, J. P., & Moeschberger, M. L. (2003). *Survival analysis: Techniques for censored and truncated data (2nd ed.)*. Springer.

Advanced Operations Research

1. Numerical optimization techniques (10)

Line search methods, gradient methods, Newton's method, conjugate direction methods, quasi-Newton methods.

2. Multiple Criteria Decision Making (15)

Basic concepts; Multiple criteria methods for finite alternatives; Multiple criteria mathematical programming problems; Goal programming; Method of global criterion and compromise programming; Interactive methods; applications and software. Ranking of Decisions-AHP and TOPSIS Methods.

3. Evolutionary Algorithms (10)

Genetic Algorithms, NSGA, PSO etc. and implementation.

4. Large Scale Optimization (15)

Introduction to computer software for solving OR problems. Introduction to large-scale optimization problems and the decomposition principle-the Benders' decomposition. Network Problems, Shortest Path Problem, Multi-Period Problems, Scheduling Decisions, Set covering and Max Flow problems.

References

1. Ravindran, A. R. (2016). *Operations research and management science handbook*. CRC Press.
2. Hillier, F. S., & Lieberman, G. J. (2015). *Introduction to operations research (10th ed.)*. McGraw-Hill

2.4 Fourth Semester Courses

Dissertation (100) (Period: January to February, 8 weeks)

The dissertation has no specific syllabus but consists of all the topics covered till the third semester and such other related topics as deemed necessary by the guide. It is typically expected to be completed by the end of February, unless an extension is granted by the Teachers' Committee or the Dean of Studies / Associate Dean.

Two copies of the dissertation duly certified by the supervisor are to be submitted to ISI on completion of the work.

Project/Dissertation (300) (Period: March to June, 16 weeks)

Each student is required to undertake a live project or dissertation focused on solving a problem related to Quality Management and/or Business Analytics, either in collaboration with an industry organization or under the guidance of the assigned supervisor. The

project/ dissertation involves the application of concepts covered in Semester I, Semester II, Semester III, and any other relevant topics as deemed necessary by the project/ dissertation supervisor.

The project should commence on the first working day of March, or on a date announced by ISI following the submission and defense of the dissertation. It is expected to continue for 16 consecutive weeks and be completed by the end of June, unless an extension is granted by the Teachers' Committee or the Dean of Studies / Associate Dean.

Two copies of the project report, duly certified by the supervisor, must be submitted to ISI upon completion of the work.

3 Evaluation procedure

Dissertation

A student of the second year of MS (QMBA) is required to do an eight-week long dissertation in the beginning of fourth 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 / Associate Dean before the end of classes of the third semester.

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

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

1. Chairman (a faculty member of ISI, who is not the supervisor of the student);
2. Convener (the supervisor of the student);
3. 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 fourth week. 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/ Associate Dean after the seminar.

Project / Dissertation

A student of the second year of MS (QMBA) is required to do a 16-week long project / 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 and the name of the organization where project will be carried out to the Dean of Studies / Associate Dean before the end of classes of the third semester.

The entire evaluation process of project/dissertation will be organized by a committee appointed by the Dean of Studies / Associate Dean.

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

1. Chairman (a faculty member of ISI, who is not the supervisor of the student);
2. Convener (the supervisor of the student);
3. Member (another faculty member of ISI or an external expert).

An interim progress report of the project / dissertation must be submitted to the supervisor by the end of the 8-weeks during the project/dissertation. The final project / 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 project / 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/ Associate Dean after the seminar.