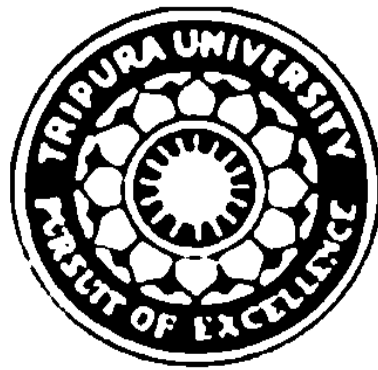


SYLLABUS FOR CBCS MSc COURSE IN STATISTICS



TRIPURA UNIVERSITY
(A Central University)
Suryamaninagar, Tripura – 799022.

2020

Tripura University (A Central University)
Department of Statistics
Choice Based Credit System MSc Statistics Syllabus
(Effective from Academic Session 2020-21)

Semester	Code and Name of the Core Courses (Credits)	Code and Elective Courses (Credits)
I	STAT 701C : Measure Theory, Probability and Distribution Theory (04) STAT 702C : Demography and Sampling Techniques (04) STAT 703C : R Programming (04) STAT 704C : Practical I (04)	STAT 705E: Basic Statistics (04) STAT 706E: Mathematical Analysis and Numerical Methods (04)
II	STAT 801C : Statistical Inference (04) STAT 802C : Linear Models and Matrix Theory (04) STAT 803C : Economic and Industrial Statistics (04) STAT 804C : Practical II (04)	STAT 805E: Statistics for National Development and Official Statistics (04) Computer Skill (From IT Departments) (04)
III	STAT 901C : Multivariate Statistics (04) STAT 902C : Experimental Designs (04) STAT 903C : Practical III (04) STAT 904C : Project I (04)	STAT 905E : Operations Research (04) Inter-Disciplinary Elective (From Other Departments) (04)
IV	STAT 1001C : Stochastic Processes, Reliability Theory and Survival Analysis (04) STAT 1002C : Econometrics, Decision Theory and Bayesian Analysis (04) STAT 1003C : Practical IV (04) STAT 1004C : Project II (08)	STAT 1005 E: Advanced R and Python Programming (04)

Minimum Credits Required for MSc in Statistics: 80 (Eighty) Credits.

STAT 701C: Measure Theory, Probability and Distribution Theory (04)

Classes of sets, fields, sigma-fields, minimal sigma-field, Borel sigma field. Measures and their elementary properties. Measurable functions, Lebesgue measures, Lebesgue-Stieltjes measures and signed measure. Integration, monotone convergence theorem, Fatou's lemma, dominated convergence theorem. Absolute continuity. Radon Nikodym theorem, Product measures, Fubini's theorem.

Basics of probability spaces, random variables, expectations and moments. Basic theorems on probability. Basic, C_r , Markov's, Holder's, Minkowski, Jensen's, Liapounov's, inequalities.

Characteristic function and their elementary properties, moments and applications, uniqueness theorem (statement only), inversion theorem and its applications, continuity theorem, Polya's conditions (statement only), Bochner's theorem(statement only). Bivariate and multivariate characteristic functions. Convergence of a sequence of random variables: convergence in probability, almost sure convergence, convergence in r^{th} mean and in distribution, their relationship.

Definition of independence, Borel-Cantelli lemma, Borel 0-1 law and Kolmogorov's 0-1 law, Chebyshev's and Khinchine's WLLN, necessary and sufficient condition for the WLLN, Kolmogorov's inequalities (statement only), SLLN and Kolmogorov's theorem.

Central limit theorem, Lindeberg-Levy and Liapunov forms of CLT. Statement of Lindeberg-Feller's CLT and examples.

Probability Distribution- Bernoulli, Binomial, Multinomial, Hypergeometric, Poisson, Geometric and Negative binomial distribution, Uniform, Exponential, Cauchy, Beta, Gamma, Normal, t, F and chi-square distributions. Power series distribution and various distributions as its particular cases. Exponential family of distributions.

Order statistics and their distributions and properties. Joint and marginal distributions of order statistics. Extreme values and their asymptotic distribution (statement only) with applications. Distributions of range, asymptotic distributions of sample median and sample quantiles.

Properties of distribution functions and characteristic functions, marginal and conditional distributions of bivariate discrete and continuous distributions, compound, truncated and mixture of distributions, concepts of convolution.

Suggested Books:

- [1] Ash, R.B. and Doleans-Dade, C.A.: Probability and Measure Theory. Elsevier.
- [2] Billingsley, P: Probability and Measure. John Wiley.
- [3] Basu, A. K: Measure Theory and Probability. Prentice Hall of India.
- [4] Bhat, B.R: Modern Probability Theory. New Age International Publishers.
- [5] Chung, K. L: A Course in Probability Theory. Academic Press, New York.
- [6] Feller, W: An Introduction to Probability Theory and its Applications, Vol I. John Wiley.
- [7] Johnson, N.L., Kotz, S. and Balakrishnan, N: Discrete Univariate Distributions. John Wiley.
- [8] Johnson, N.L., Kotz, S. and Balakrishnan, N: Continuous Univariate Distributions. John Wiley.
- [9] Mood, M, Graybill, F. A and Bose, D.C: Introduction to the Theory of Statistics. Tata McGraw-Hill, New Delhi.
- [10] Rohatgi, V.K: An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern, New Delhi.

STAT 702C: Demography and Sampling Techniques (04)

Demography: Sources of demographic data, Rates and ratios of vital events. The life table, its constitution and properties. Makehams and Gompertz curves. Abridged life tables. Stable and stationary populations. Different birth rates. Total fertility rate. Gross and net reproduction rates. Different mortality rates. Standardized death rate. Internal and international migration: net migration. Inter-censal and post-censal estimates. Projection methods including logistic curve, fitting.

Sampling Techniques: Basic concepts of finite population and sampling techniques. Simple random sampling – with and without replacements, characteristics and methods of selection, estimation of population mean/total, standard error and its estimate, determination of sample size.

Stratified random sampling – definition, method of selection, estimation of population mean/total with standard error and its estimate, problems of allocations-proportional and optimum, comparison with unrestricted sampling.

Systematic sampling – method of selection, estimation of population mean/total, sampling variance, comparison with simple random sampling and stratified sampling.

Cluster sampling – equal and unequal size, estimation of population mean/total, standard error and its estimation, comparison with mean per unit estimator. Two-stage sampling with equal and unequal first stage units, estimation of population mean/total, standard error and its estimation, comparison with single-stage sampling.

Use of auxiliary information in sample surveys. Methods of estimation – ratio, product, difference and regression methods, sampling variance and efficiency of the estimators.

Concept of sampling design, sampling scheme, estimator, sampling strategy, Unequal probability sampling with replacement – probability proportional to size with replacement sampling, estimation of mean/total, method of selection, standard error of estimate and its estimation, comparison with SRSWR, gain due to PPSWR sampling.

Unequal probability sampling without replacement – Des Raj's ordered estimator, Murthy's unordered estimator, Horvitz-Thompson estimator of population mean/total and estimate of variance, Yates-Grundy estimator of variance. Midzuno Scheme of Sampling, and Rao-Hartly-Cochran sampling procedures.

Problems of non response – Hansen and Hurwitz technique, Politz-Simon technique. Randomized response techniques – Warner's model and unrelated question model. Variance estimation – methods of random groups, the Jack knife, balanced half sample, and the bootstrap. Small area estimation – direct, synthetic and composite estimators.

Suggested Books:

- [1] Cochran, W. G: Sampling Techniques. Wiley Eastern.
- [2] Sampath, S: Sampling Theory and Methods. Narosa Publishing House.
- [3] Singh, Daroga and Chaudhary, F. S: Theory and Analysis of Sample Survey Designs. New Age International (P) Limited Publishers.
- [4] Mukhopadhyay, Parimal: Theory and Methods of Survey Sampling. Prentice Hall.
- [5] Murthy, M. N: Sampling Theory and Methods. Statistical Publishing Society.
- [6] Mukhopadhyay, Parimal: Small Area Estimation in Survey Sampling. Narosa Publishing House.
- [7] Sukhatme, P.V. and Sukhatme, B.V.: Sampling Theory of Surveys with Applications, Piyush Publications, New Delhi.
- [8] Keyfitz, N: Applied Mathematical Demography, Springer Verlag.
- [9] Chattopadhyay, A. K. & Saha, A. K. : Demography: techniques and analysis
- [10] Chiang, C. L. : Introduction to Stochastic Processes in Biostatistics
- [11] Shryock, H. S. et.al.: The Methods and Materials of Demography
- [12] Keyfitz, N.: Applied Mathematical Demography

STAT 703C: R Programming (04)

Data types in R: numeric, character, logical; real, integer, complex, strings and the paste command, matrices, dataframes, lists, setwd, read.table, read.csv, write.matrix, write.csv, creation of new variables, categorisation, cut, factor; round, apply, creation of patterned variables, saving output to a file; source; print, saving workspace/history.

Graphics in R: the plot command, histogram, barplot, boxplot, points, lines, segments, arrows, paste, inserting mathematical symbols in a plot, pie diagram, customisation of plot- setting graphical

parameters, text and mtext, the pairs command, colours and palettes, saving to a file; graphical parameters such as mar/mai/mfrow, xlab/ylab/las/xaxp/yaxp/xlim/ylim /cex/axis/tck/srt main/title/legend/locator, identify.

Basic Statistics: r help-command help, help.search(), R mailing list, contributed documentation on cran, one and two sample t tests, bartlett's test for variance, f test for equality of variances, multi sample means, chi squared tests - homogeneity, independence, exact tests and confidence intervals, checking the assumptions, distribution fitting.

Vector matrix operations: matrix operations, addition, subtraction, multiplication, linear equations and eigenvalues, matrix decomposition and inverse, the linear model and qr decomposition, determinant, g inverse, finding a basis, orthonormalisation, finding rank.

Linear models: the lm function; fitting a linear model; anova/ancova/regression models, the summary function, goodness of fit measures, predicted values and residuals; residual plots, the anova table, confidence intervals.

R functions: some useful inbuilt R functions - sort, order, rank, ceiling, floor, round, trunc, signif, apply, lapply, by, programming in R- for/while/if loops, functions, the source command.

Random number generation and simulations: rnorm, rchisq, rt, rbinom etc; sample; set.seed, monte carlo techniques, problems on monte carlo techniques.

Regression: case study from regression analysis.

R libraries: what is an r library? How to load a library? How to use an unknown library? How to get help-documentation and vignettes?

Suggested Books:

- [1] Randall L. Eubank and Ana Kupresanin: Statistical Computing in C++ and R. Chapman & Hall/CRC The R Series.
- [2] Verzani, John. Using R for Introductory Statistics. Taylor & Francis.

STAT 704C: Practical I (04)

Practical Based on Core Papers of this Semester (other than R programming paper).

STAT 705E: Basic Statistics (04)

Types of statistical data: primary and secondary data, Classification, Tabulation and Diagrammatic representation of data, Frequency Distribution, Cumulative Distribution and their graphical representation, Histogram, Frequency Polygon, Frequency Curve and Ogive.

Measures of central tendency: Arithmetic geometric and harmonic mean, median and mode. Measures of dispersion: Mean Deviation, Variance, moments, skewness and kurtosis and their measures based on quantiles and moments.

Correlation Coefficient and its Properties, Spearman's Rank Correlation Coefficient. Correlation and Regression Analysis, Fitting of Linear equation by the principle of Least Squares. Partial and multiple correlation.

Random Experiments and Random Events, Classical and Axiomatic definitions of Probability (discrete sample space only), Conditional Probability, Independence of Events and Bayes Theorem.

Random Variable and its Probability Distribution, Cumulative Distribution Function, Probability Mass Function and Probability Density Function, Mathematical Expectation, Variance and Moments, Simple Theorems including theorems on expectation and variance of a sum of random variables and expectation of product of Random Variables . Moment generating functions; characteristic functions; probability inequalities (Tchebyshef, Markov, Jensen).

Introduction of some distributions: Bernoulli, Binomial, Poisson, Geometric, Uniform, Normal, Exponential distributions.

Population, sample, Statistic, standard error, estimation, confidence interval and confidence level, confidence interval estimate of proportion and mean. Hypothesis and its types, errors, critical region, level of significance, power and p-values. Test statistics: Student's t-test, Chi-square, F and Z-Statistics and their applications in testing of hypothesis. Exact and Large sample tests. Analysis of Variance. Non-parametric test - sign, median, run, Mann-Whitney test. Chi square test of goodness of fit, Chi square analysis of contingency table.

Suggested Books:

- [1] Mukhopadhyay, P: Mathematical Statistics. Books and Allied (P) Ltd.
- [2] Mukhopadhyay, P: Applied Statistics. Books and Allied (P) Ltd.
- [3] Goon, A. M., Gupta, M. K and Dasgupta, B.: Fundamentals of Statistics; Vol. I, II
- [4] Rohatgi, V.K. and Ehsanes Saleh, A. K. Md. : An introduction to Probability and Statistics

STAT 706E: Mathematical Analysis and Numerical Methods (04)

Mathematical Analysis: Real number system, cluster points of sets, closed and open sets, compact sets, Bolzano-Weierstrass property and Heine-Borel property (statement and use), sets of real vectors.

Sequence, series, convergence, real valued function, limit, continuity, uniform continuity, differentiability of univariate and multivariate functions.

Sequence and series of functions, uniform convergence, power series.

Riemann integral, Riemann Stieltjes integral, Multiple integral.

Analytic function, Cauchy-Riemann equations. Statement of Cauchy theorem and of Cauchy integral formula with applications, Taylor's series. Singularities, Laurent series. Residue and contour integration.

Fourier and Laplace transforms.

Numerical Methods: Finite differences of different orders - Δ , E and D operators, factorial representation of a polynomial, separation of symbols, sub-division of intervals, differences of zero.

Concept of interpolation and extrapolation - Newton Gregory's forward and backward interpolation formulae for equal intervals, divided differences and their properties, Newton's formula for divided difference, Lagrange's formula for unequal intervals, central difference formula due to Gauss, Sterling and Bessel, concept of error terms in interpolation formula.

Inverse interpolation - Different methods of inverse interpolation.

Numerical solution of algebraic equation, Solutions on linear system, direct method, Gauss elimination method, matrix-inversion, eigenvalue problems.

Numerical differentiation - Trapezoidal, Simpson's one-third and three-eighth rule and Waddles rule.

Summation of Series - Whose general term (i) is the first difference of a function (ii) is in geometric progression.

Numerical solutions of differential equations - Iteration method, Euler's Method, modified Euler's method, Milne's Method, Picard's Method and Runge-Kutta Method.

Suggested Books:

- [1] Ralston A , S. A first course in Numerical Analysis, Mc Graw Hill , N. Y(1965)
- [2] Hildebrand, F. B. Introduction to Numerical Analysis, Mc GrawHill N. Y 4. Ames W. F. Numerical methods for Partial Differential equations , Academic press N.Y. 1977
- [3] K.E. Atkinson, Introduction of Numerical Analysis, 2nd Edition, John Wiley, 1989.
- [4] Numerical Mathematical Analysis – J. B. Scarborough, Oxford & IBH Publishing Co., 2001.
- [5] Goldberg, R. R. : Methods of Real Analysis.
- [6] Burkill , J. C.: First Course of Mathematical Analysis.
- [7] Ahlfors: Complex Analysis.
- [8] Rudin.W: Principles of Mathematical Analysis. Mc Graw Hill

- [9] Malik .S.C. and Arora, S: Mathematical Analysis. Wiley Eastern Ltd.
- [10] Jain, P. K and Kaushik, K. K: An Introduction to Real Analysis. S. Chand.
- [11] Apostol, T.M: Mathematical Analysis. Addison- Wesley.
- [12] Bartle, R.G: Elements of Real Analysis. John Wiley & Sons.
- [13] Berbarian, S.K: Fundamentals of Real Analysis. Springer-Verlag.

STAT 801C: Statistical Inference (04)

Theory of Estimation: Methods of estimation: maximum likelihood method, method of moments, minimum chi-square method, least-squares method. Unbiasedness, efficiency, consistency. Sufficient statistics, Fisher-Neyman factorisation theorem and obtaining sufficient statistic. Minimal sufficient statistics and exponential family, sufficiency and completeness, sufficiency and invariance. Uniformly minimum variance unbiased estimators. Rao-Blackwell theorem and Lehmann-Scheffe theorem. Cramer-Rao lower bound and Bhattacharya system of lower bounds in the single-parameter regular case. Cramer-Rao linequality. Estimation by confidence intervals.

Tests of hypothesis: Simple and composite hypotheses, two types of errors, critical region, review of notions of nonrandomized and randomized tests, level, size, power function, generalized Neyman-Pearson lemma (Sufficiency part only), fundamental Neyman-Pearson lemma (Proof: Existence and Sufficiency parts), UMP Tests. Monotone Likelihood ratio. UMPU Tests, one parameter exponential family (without derivation). Concepts of locally most powerful tests. Similar tests, Neyman structure, UMPU tests for composite hypotheses.

Likelihood ratio test, its properties and its asymptotic distribution. Applications of the LR method. Sequential tests, SPRT and its properties, Wald's fundamental identity, OC and ASN functions. Sequential estimation.

Nonparametric tests: U-statistics, Kernel and systematic kernel. Test for randomness, Sign test, Median test, Mann-Whitney test, Wilcoxon test for one and two-samples, rank correlation and test of independence. Kolmogorov-Smirnov Test, Kruskal-Walli Test, Friedman test.

Suggested Books:

- [1] Kale, B. K: A first Course on Parametric Inference. Narosa Publishing House.
- [2] Lehmann E. L: Theory of Point Estimation. John Wiley.
- [3] Lehmann, E. L: Testing Statistical Hypotheses. John Wiley.
- [4] Rao, C. R: Linear Statistical Inference and Its Applications. Wiley Eastern.
- [5] Mukhopadhaya, P: Mathematical Statistics. Books and Allied (P) Ltd.
- [6] Wald, A: Sequential Analysis. John Wiley, NY.
- [7] Gibbons, J.D. & Chakraborti, S: Nonparametric Statistical Inference. Marcel Dekker.
- [8] Randles, R.H. and Wolfe, D.A: Introduction to the Theory of Nonparametric Statistics. John Wiley.
- [9] Lehmann, E. L: Nonparametrics: Statistical Methods Based on Ranks. Spinger.

STAT 802C: Linear Models and Matrix Theory (04)

Matrix Theory : Elementary operations, reduced row-echelon form, consistency of system of equations, solutions of systems of equations, homogeneous system, inverse of a matrix, determinants, Cramer's rule. Vector spaces and subspaces, linear independence of vectors, basis, linear transformations and matrices, kernel, nullity theorem, rank of a matrix. Inner Product spaces, C-S inequality, triangle inequality, orthonormal basis, Gram-Schmidt construction of orthonormal basis. Basics of theory of matrices and determinants, row and column spans of real matrices, rank, elementary matrices, idempotent matrices,

eigenvalues and eigenvectors of a matrix, spectral decomposition of a real symmetric matrix, definiteness-positive, non-negative of real matrices, g-inverses: existence and definition, some important results on g-inverses, bilinear and quadratic forms, extrema of quadratic forms.

Linear Models : Linear statistical models, illustrations, Gauss-Markov model, normal equations and least square estimators, estimable linear functions, g-inverse and solution of normal equations. Error space and estimation space. Variances and covariances of BLUEs. Estimation of error variance, estimation with correlated observations, least squares estimates with restriction on parameters. Simultaneous estimates of linear parametric functions. Fundamental theorems of least squares and applications to the tests of linear hypotheses. Test of hypotheses for one and more than one linear parametric functions. Fisher-Cochran theorem, distribution of quadratic forms. SS of a linear estimate of an estimable function, set of linear estimate, df etc. Sheffe's and Tukey's approach.

Simple and multiple linear regressions, fit of polynomials and use of orthogonal polynomials.

Analysis of Variance - fixed, mixed and random effect models. Analysis of covariance.

Suggested Books:

- [1] Datta, K.E: Matrix and Linear Algebra, Prentice-Hall of India Private Ltd.
- [2] Rao, C.R: Linear Statistical Inference and its Applications, Wiley Eastern Ltd.
- [3] Searle, S.R: Matrix Algebra useful for Statistics, John Wiley, NY.
- [4] Kshirsagar, A M: A Course in Linear Models. Marcel Dekker, N. Y.
- [5] Joshi, D D: Linear Estimation and Design of Experiments. New Age International Publication.
- [6] Mukhopadhyay, P: Mathematical Statistics. Books and Allied (P) Ltd.
- [7] Weisberg, S. Applied Linear Regression. Wiley.
- [8] Chatterjee, S. and Price, B: Regression Analysis by Example. John Wiley, New York.
- [9] Goon, A.M., Gupta, M.K. and Dasgupta, B: An Outline of Statistical Theory, Vol II. The World Press.
- [10] Hoffman, K. and Kunze, R., Linear Algebra, second edition, Prentice-Hall, New Delhi, 1978.
- [11] Rao, A. R. and Bhimashankaram, P., Linear Algebra, second edition, TRIMHindustan Book Agency, 2000.
- [12] Rao, C. R., Linear Statistical Inference and Its Applications, second edition, Wiley Eastern, 1973.

STAT 803C: Economic and Industrial Statistics (04)

Index numbers of prices and quantities and their relative merits. Construction of index numbers of wholesale and consumer prices. Income distribution-Pareto and Engel curves.

Components of time series. Methods of their determination. Variate difference method, Yule-Slutsky effect. Correlogram. Autoregressive models of first and second order. Periodogram analysis.

Time series as discrete parameter stochastic process. Auto covariance and auto correlation functions and their properties. Detailed study of the stationary processes: moving average (MA), auto regressive (AR), ARMA and AR integrated MA (ARIMA) models. Box-Jenkins models. Discussion (without proof) of estimation of mean, auto covariance and auto correlation functions under large sample theory. Choice of AR and MA periods. Estimation of ARIMA model parameters. Spectral analysis of weakly stationary process. Periodogram and correlogram analysis. Forecasting: exponential and adaptive smoothing methods.

Control charts for variables and attributes, CUSUM Chart and V-masks; Acceptance sampling by attributes; single, double and sequential sampling plans; OC and ASN functions, AOQL and ATI; Acceptance sampling by variable-use of Dodge-Romig and other tables. Tolerance limits.

Capability indices C_p , C_{pk} and C_{pm} . Estimation, confidence intervals and tests of hypotheses relating to capability indices for normally distributed characteristics.

Suggested Books:

- [1] Montgomery, D. C: Introduction to Statistical Quality Control. John Wiley.
- [2] Wetherill, G B and Brown, D W: Statistical Process Control - Theory and Practice. Chapman and Hall.
- [3] Biswas, S: Statistics of Quality Control, Sampling Inspection and Reliability. New Age International Publishers.
- [4] Mittage, H.J and Rinne, H: Statistical Methods of Quality Assurance. Chapman Hall.
- [5] Mahajan, M: Statistical Quality Control. Dhanpat Rai & Co Private Ltd., New Delhi.
- [6] Gupta, H.D: Quality assurance through ISO 9000. South Asia Publication, New Delhi.
- [7] Box, G.E.P and Jenkins, G.M: Time Series Analysis - Forecasting and Control. Holden-day, San Francisco.
- [8] Anderson, T. W: The Statistical Analysis of Time Series. Wiley, N. Y.
- [9] Montgemory, D. C and Johnson, L. A: Forecasting and Time Series Analysis. McGraw Hill.
- [10] Kendall, Sir Maurice and Ord, J. K: Time Series. Edward Arnold, London.
- [11] Mukhopadhyay, P: Applied Statistics. Books and Allied (P) Ltd. Publising, New Delhi.

STAT 804C: Practical II (04)

Practical Based on Core Papers of this Semester.

STAT 805E: Statistics for National Development and Official Statistics (04)

Concept of economic development – role of statistics, growth in per capita income and distributive justice. Indices of development, Human Development Index.

Estimation of National Income - product approach, income approach and expenditure approach.

Measures of unemployment.

Population growth in developing and developed countries. Population projection using Leslie matrix. Labour force projection.

Measuring inequality of incomes, Gini coefficient, Theil's measure. Poverty measurement different issues, measures of incidence and intensity, combined measures, eg. Indices due to Kakwani, Sen. etc.

Introduction to Indian and International statistical systems. Role, function and activities of Central and State statistical organizations. Organization of large scale sample surveys.

Role of National Sample Survey Organization. General and special data dissemination systems.

Population growth in developed and developing countries, evaluation of performance of family welfare programmes, projections of labour force and manpower. Scope and content of population census of India.

System of collection of Agricultural Statistics. Crop forecasting and estimation, productivity, fragmentation of holdings, support prices, buffer stocks, impact of irrigation projects.

Statistics related to industries, foreign trade, balance of payment, cost of living, inflation, educational and other social statistics.

Suggested Books:

- [1] Basic Statistics Relating to the Indian Economy (CSO) 1990.
- [2] Guide to Official Statistics (CSO) 1999.
- [3] Statistical System in India (CSO) 1995.
- [4] Principles and accommodation of National Population Censuses, UNESCO.
- [5] Panse, V. G., Estimation of Crop Yields (FAO).
- [6] Family Welfare Yearbook. Annual Publication of D/o Family Welfare.
- [7] Monthly Statistics of Foreign Trade in India, DGCIS, Calcutta and other Govt. Publications.

- [8] Keyfitz, N: Applied Mathematical Demography, Springer Verlag.
- [9] UNESCO: Principles for Vital Statistics Systems. Series M -12.
- [10] David B. Grusky, S. M. Ravi Kanbr, Amartya Kumar Sen: Poverty and Inequality. Standford Univ. Press.
- [11] Chaubey Y. P: Poverty Measurements: Issues, Approaches and Indices. New Age International (P) Limited.
- [12] UNO: Yearly Human Development Reports.
- [13] World Bank: Yearly Reports.
- [14] CSO. National Accounts Statistics- Sources and Health.
- [15] Sen, A. (1997). Poverty and Inequality.
- [16] Datt R., Sundharam, K. P. M. (Revised edition). Indian Economy, (Sultan Chand & company Ltd.)

STAT 901C: Multivariate Statistics (04)

Multivariate normal distribution – distribution of linear combination of normally distributed variables, marginal and conditional distributions, distribution of quadratic forms. Random sampling from normal distribution, maximum likelihood estimators of parameters, distributions of sample mean vector and matrix of corrected sum of squares and cross products.

Estimation of partial and multiple correlation coefficients and their sampling distributions (null case only). Hotelling's T^2 statistic – properties, distribution and uses, tests on mean vector for one and more multivariate normal populations and also on equality of the components of a mean vector in a multivariate normal population. Mahalanobis – D^2 statistic and its use.

Classification and discrimination procedures – discrimination between two multivariate normal populations, sample discriminant function, tests associated with discriminant functions, probabilities of misclassification and their estimation, classification into more than two multivariate normal populations. Fisher's discriminant function.

Wishart matrix – distribution and properties, characteristic function, reproductive property, marginal and conditional distributions. Distribution of sample generalized variance.

Principal components – definition, MLE of principal components and their variances. Canonical variables and canonical correlations – definition, use, estimation and computation.

Suggested Books:

- [1] Anderson, T.W: An introduction to Multivariate Statistical Analysis. John Wiley.
- [2] Giri, N.C: Multivariate Statistical Inference. Academic Press, NY
- [3] Bhuyan, K. C: Multivariate Analysis and Its Applications. New Central Book Agency (P) Ltd.
- [4] Kshirsagar, A.M: Multivariate Analysis. Marcel Decker.
- [5] Rao, C.R: Linear Statistical Inference and Its Application. John Wiley.
- [6] Sharma, S: Applied Multivariate Techniques, John Wiley.
- [7] Srivastva, M.S. and Khatri, C.G: An Introduction to Multivariate Statistics. North Holland.
- [8] Anderson, T.W.: An Introduction to Multivariate Statistical Analysis, 2nd ed., Wiley
- [9] Morrison, D.F.: Multivariate Statistical Methods, 2nd ed., McGraw-Hill.

STAT 902C: Experimental Designs (04)

Design of Experiments: Basic principles of experimental design. Randomisation structure and analysis of completely randomised, randomised blocks and Latin square designs. Analysis of missing plot technique.

Factorial experiments. Analysis of 2^n factorial experiments in randomised blocks.

Split Plot Design, Strip-Plot Design and their applications.

Incomplete block designs; Balanced, connectedness and orthogonality, BIBD with recovery of inter-block information; Group Divisible Design, PBIBD with 2 associate classes. Quasi-Latin square designs, Youden square design, Lattice design, Mutually orthogonal Latin square (MOLS) design.
Analysis of covariance. Analysis of non-orthogonal data.
Factorial experiments, complete confounding and partial confounding.
Optimality criteria for experimental designs.
Design for study of response surfaces; first and second order designs.

Suggested Books:

- [1] Dean, Angela and Voss, Daniel: Design and Analysis of Experiments. New Age International.
- [2] Das, M.N. and Giri, N.: Design and Analysis of Experiments. New Age International.
- [3] Joshi, D.D.: Linear Estimation and Design of Experiments. New Age International.
- [4] Khuri, A. and Cornell, M.: Response Surface Methodology. Marcel Dekker.
- [5] Montgomery, C.D.: Design and Analysis of Experiments. John Wiley, New York.
- [6] Mukhopadhyay, P: Applied Statistics. Books and Allied (P) Ltd.
- [7] Gupta, S.C and Kapoor, V. K: Fundamentals of Applied Statistics. Sultan Chand.

STAT 903C: Practical III (04)

Practical Based on Core Papers of this Semester (other than R programming paper).

STAT 904C: Project I (04)

Survey based / Review based report preparation and presentation.

STAT 905E: Operations Research (04)

Definition and scope of Operations Research, phases in Operations Research, models and their solutions.
Review of linear programming problems, duality in linear programming, duality theorem and dual simplex method. Parametric programming: parameterization of the cost vector 'c', parameterization of requirement vector 'b'. Sensitivity analysis: variation in cost vector 'c', variation in the requirement vector 'b', addition and deletion of single variable and addition and deletion of single constraint.
Integer programming: all integer and mixed programming problem, Gomory's cutting plane method.
Nonlinear programming: Kuhn Tucker conditions, quadratic programming problems, Wolfe's and Beale's methods for solving.
Introduction to decision analysis: pay-off table for one-off decisions and discussion of different decision criteria, decision trees. Decision-making in the face of competition, two-person games, pure and mixed strategies, existence of solution and uniqueness of value in zero-sum games, finding solutions in 2×2 , $2 \times m$ and $m \times n$ games.
Sequencing and scheduling problems. 2 machine n-job and 3-machine n-job problems with identical machine sequence for all jobs; 2-job n-machine problem with different routings.
Replacement problems: block and age replacement policies, replacement of items with long life.
Queuing theory: basic characteristics of queuing models, arrival and service distribution, steady-state solutions of M/M/1 and M/M/C models.
Inventory problems and analytical structure, EOQ formula. Deterministic inventory systems with and without lead-time. Single period stochastic models of inventory controls.
Network Analysis: PERT and Critical Path Methods(CPM).

Suggested Books:

- [1] Taha H A: Operational Research - An Introduction. Macmillan.
- [2] Kanti Swarup, Gupta ,P.K. and Singh, M.M: Operations Research. Sultan Chand and Sons.
- [3] Sinha, S M: Mathematical Programming - Theory and Methods, Elsevier.
- [4] Hadley G and Whitin T M: Analysis of Inventory Systems. Prentice Hall.
- [5] Starr, M K and Miller, D W: Inventory Control - Theory and Practice. Prentice Hall.

STAT 1001C: Stochastic Processes, Reliability Theory and Survival Analysis (04)

Stochastic Processes: Notations and specification of stochastic process, stationary process, martingales, random walk and ruin problems, expected duration of the game, generating function of the duration of the game and for the first passage times, random walk in the plane and space. Markov chains - classification of states and chains, and related problems.

Determination of higher transition probabilities, stability of a Markov system, limiting behavior of finite irreducible chains, ergodic theorem, graph theoretic approach, Reducible Markov Chains.

Markov processes with discrete state space – Poisson process, properties of Poisson process, Poisson process and related distributions. Generalization of Poisson process – Pure birth process, Yule-Furry process, Pure death process, birth and death processes.

Markov processes with continuous state space – Brownian motion, Wiener process, differential equations for a Wiener process, Kolmogorov equations, first passage time distribution for Wiener process.

Reliability Theory: Life distributions, reliability function, hazard rate, mean residual life, common univariate life distributions viz. exponential, gamma, Weibull, lognormal, Rayleigh etc.

Notions of ageing: IFR, IFRA, NBU, DMRL and NBUE classes and their duals and relationships between them, loss of memory property of the exponential distribution.

Series and parallel systems. Reliability concepts and measures, components and systems, coherent systems, reliability of coherent systems.

Survival Analysis: Estimation of survival function from censored data: Actuarial estimator, Kaplan-Meier estimator.

Regression model for survival data, Cox's proportional hazard model, Accelerated failure time model.

Suggested Books:

- [1] Barlow R.E. and Proschan F: Statistical Theory of Reliability and Life Testing. Rinehart and Winston.
- [2] Nelson, W: Applied Life Data analysis. John Wiley.
- [3] Sinha, S.K: Reliability and Life Testing, Wiley.
- [4] Zacks, S: Reliability Theory. Springer Verlag.
- [5] Biswas, S: Statistics of Quality Control, Sampling Inspection and Reliability. New Age International Publishers.
- [6] R. E. Elandt – Johnson and N. L. Johnson: Survival models and data analysis.
- [7] Adke, S. and Manjunath, S.M: An Introduction to Finite Markov Process. Wiley Eastern.
- [8] Bhatt, B.R: Stochastic Models - Analysis and Applications. New Age International.
- [9] Medhi, J: Stochastic Process. Wiley Eastern.
- [10] Prabhu, N.U: Stochastic Processes: Basic Theory and its Applications. World Scientific.
- [11] Ross, S.M: Stochastic process. John Wiley and Sons.

STAT 1002C: Econometrics, Decision Theory and Bayesian Analysis (04)

Nature of Econometrics. The general linear model (GLM) and its extensions. Ordinary least squares (OLS) estimation and prediction.. Generalized least squares (GLS) estimation and prediction.

Heteroscedastic disturbances. Multicollinearity problem, its implications and tools for handling the problem. Ridge regression. Instrumental variable, Use of dummy variables and seasonal adjustment, Errors in variables.

Decision theory – composition, decision and risk functions, Nonrandomized Decision Rules, randomization. Optimal decision rules – ordering of the decision rules, geometrical interpretation.

Theorems of decision theory – admissibility and completeness, existence and admissibility of Bayes' rules, existence of a minimal complete class.

The separating hyperplane theorem, essential completeness of the class of non-randomised decision rules, Jensen's inequality, the minimax theorem, the complete class theorems and their applications, solving of minimax rules.

Sufficient statistics, essential complete class of rules based on sufficient statistics, exponential families of distributions, complete sufficient statistics and their applications.

Bayesian estimation – Different loss functions, choice of prior distributions, Point estimation, Bayesian Computation.

Suggested Books:

[1] Box, G.E.P and Jenkins, G.M: Time Series Analysis - Forecasting and Control. Holden-day, San Francisco.

[2] Anderson, T. W: The Statistical Analysis of Time Series. Wiley, N. Y.

[3] Montgemory, D. C and Johnson, L. A: Forecasting and Time Series Analysis. McGraw Hill.

[4] Kendall, Sir Maurice and Ord, J. K: Time Series. Edward Arnold, London.

[5] Brockwell, P.J. and Davis, R.A: Time Series-Theory and Methods. Springer - Verlag.

[6] Madnani, G. M. K: Introduction to Econometrics - Principles and applications. Oxford and IBH

[7] Berger, J. O: Statistical Decision Theory and Bayesian Analysis. Springer.

[8] Ferguson, T. S: Mathematical Statistics - A Decision Theoretic Approach. Academic Press.

[9] Bansal, A. K: Bayesian Parametric Inference. Narosa Publishing House.

[10] Box, G.E.P. and Tiao, G.C: Bayesian Inference in Statistical Analysis. Addison and Wesley.

[11] De. Groot, M.H: Optimal Statistical Decisions. McGraw Hill.

[12] Sinha, S.K: Bayesian Estimation. New Age International.

STAT 1003C: Practical IV (04)

Practical Based on Core Papers of this Semester.

STAT 1004C: Project II (08)

Part I: Final project writing & submission

Part II: Seminar presentation.

STAT 1005E: Advanced R and Python Programming (04)

R Programming : Programming based on Multivariate Statistics, Experimental Designs, Simple & Multiple Linear Regression, Variable Selection, Model Building & Model Diagnostics, Time Series Analysis and Industrial Statistics.

Python Programming : Basic Idea; Simple Syntax; Basic Operations; Different Libraries; Function; Loop; Array; Data handling and management; Chart and Diagrams; Random Number Generation from a known and unknown distribution; Simulation; Application in various Statistical field; Idea of Parallel Computing and/or Efficient Programming

Suggested Books:

- [1] Everitt, Brian and Hothorn, Torsten: An Introduction to Applied Multivariate Analysis with R, Springer.
- [2] Wiley, Matt and Wiley, Joshua F: Advanced R Statistical Programming and Data Models, Springer.
- [3] Basin, H : Python for Beginners, New Age International, New Delhi.
- [4] Padmanabhan, T.R : Programming with Python, Springer.
