WestBengal State University

Detailed Syllabus for Four-years Under Graduate Programme In STATISTICS

Under Curriculum and Credit Framework for Undergraduate Programmes

Based on

National Education Policy, 2020

Syllabus for 4-year Undergraduate Programme
(Honours / Honours with Research)
Major Papers
Semester-I

STSDSC101T–Descriptive Statistics-I and Probability Theory-I

[Credit3] **[45 LectureHours]**

Unit1: Statistical Data **[12LectureHours]**

Statistics: Definition and scope. Concepts of statistical population and sample. Data: quantitative and qualitative, cross-sectional and time-series, discrete and continuous. Scales of measurement: nominal, ordinal, interval and ratio. Collection of data, concept of questionnaire. Presentation of data: tabular and graphical. Frequency distributions, cumulative frequency distributions and their graphical representations. Stem and leaf displays.

Unit2: Univariate Data Analysis **[15LectureHours]**

Measures of Central Tendency: Mean, Median, Mode. Measures of Dispersion: Range, Mean deviation, Standard deviation, Coefficient of variation, Gini's Coefficient, Lorenz Curve. Moments, skewness and kurtosis. Quantiles and measures based on them. Box Plot. Outliers and its detection using quantiles. Trimmed mean.

Unit3: Introduction to Probability **[18 Lecture Hours]**

Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability: classical, statistical and axiomatic. Probability space and different properties of probability function. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications.

STSDSC101P: List of Practicals
[Credit2] **[60 Lecture Hours]**

- Graphical representation of data.
- Problems based on construction of frequency distributions, cumulative frequency distributions and their graphical representations.
- Problems based on measures of central tendency.
- Problems based on measures of dispersion.
- Problems based on combined mean and variance and coefficient of variation.
- Problems based on moments, skewness and kurtosis.
- Problems related to quantiles and measures based on them.
- Problem of detection of outliers using quantiles, construction of boxplot.
- Numerical sums using classical definition of Probability.
- Numerical sums on conditional probability.

Reference Books

- Goon, A.M., Gupta, M.K. and Dasgupta, B.(2002):Fundamentals of Statistics, Vol. I & II, 8thEdition, World Press, Kolkata.
- Miller, Irwin and Miller, Marylees John E. Freunds(2006): MathematicalStatisticswithApplications,7thEdition, Pearson Education, Asia.
- Mood, A.M., Graybill, F.A. and Boes, D. C.(2007): Introduction to the Theory of Statistics,3rdEdition, Tata McGraw-Hill Pub. Co. Ltd.
- Tukey, J. W. (1977): Exploratory Data Analysis, Addison-Wesley Publishing Co.
- Freedman, D., Pisani, R. and Purves, R. (2014): Statistics,4thEdition, W.W. Norton & Company.
- Chung, K. L. (1983): Elementary Probability Theory with Stochastic Process, Springer/ Narosa.
- Feller, W. (1968): An Introduction to Probability Theory & its Applications, John Wiley.
- Goon, A.M., Gupta, M.K. & Dasgupta, B. (2003): An Outline of Statistical Theory Vol- I, World Press.
- Parzen, E. (1972): Modern Probability Theory and its Applications, John Wiley.
- Uspensky, J.V.(1937): Introduction to Mathematical Probability, McGraw Hill.
- Cacoullos, T.(1973): Exercises in Probability, Narosa.
- Ross, S. (2002): A First Course in Probability, Prentice Hall.
- Stirzaker, D. (2003): Elementary Probability, 2ndEdition, Cambridge University Press
- Rahman, N.A.(1983): Practical Exercises in Probability and Statistics, Griffin.
- Rohatgi, V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2nd Edition, John Wiley and Sons.

STSHSE101M/STSHSE303M/STSGSE301M/STSGSE501M –C++ Programming

[Credit2] **[90 Lecture Hours]**

Unit1: Introduction to C++ **[70 Lecture Hours]**

Components, basic structure of programming. Notion of header file. Concept of character and variable; allocation of memory. Declaration and assignment of variables and array variables. Input and output operations in C. Use of conditional operations and loops; if…else, for, while, do…while etc. dim arrays. User defined functions.

Unit 2: Applications of C++ **[20 Lecture Hours]**

Applications in Simple mathematical operations, Sorting of an array and finding quantiles, Preparing a frequency table, Mean, median and mode of a grouped frequency Data, Variance and coefficient of variation of a grouped frequency data.

Reference Books

- Kernighan, B.W. and Ritchie, D. (1988): C Programming Language, 2nd Edition, Prentice
- Balagurusamy,E. (2011):ProgramminginANSIC,6th Edition Tata McGraw
- Gottfried, B.S. (1998): Schaums Outlines: Programming with C, 2nd Edition, Tata McGraw Hill.

Semester II

STSDSC202T –Descriptive Statistics- II & Probability Theory-II

[Credit3] **[45LectureHours]**

Unit1: Bivariate Data Analysis **[12 Lecture Hours]**

Bivariate data: Definition, scatterdiagram, simple correlation, linear regression, principle of least squares, fitting of polynomial and exponential curves, correlation ratio, correlation index, intra-class correlation. Rank correlation: Spearman's and Kendall's measures.

Unit2: Categorical Data Analysis **[12 Lecture Hours]**

Analysis of Categorical Data: Contingency table, independence & association of attributes. Ideas of complete and absolute association. Yule's measures of association and colligation, Cramer's measure of association, odds-ratio.

Unit3: Random Variables & Standard Discrete and Continuous Probability Distributions-I **[21 Lecture Hours]**

Random Variables: Definition of discrete and continuous random variables, cumulative distribution function (c.d.f.) and its properties (without proof), probability mass function (p.m.f.), and probability density function (p.d.f.). Expectation and Variance. Standard discrete probability distributions I: Discrete Uniform, Binomial, Poisson; Standard continuous probability distributions I: Rectangular, Exponential, Normal.

STSDSC202P:List of Practicals

[Credit2] **[60 Lecture Hours]**

- Correlation coefficient for a bivariate frequency distribution.
- Lines of regression, angle between lines and estimated values of variables.
- Fitting of polynomials, exponential curves.
- Spearman rank correlation with and with outlies.
- Computation of correlation ratio.
- Computation of intra class correlation coefficient.
- Fitting of binomial distribution for given n and p.
- Fitting of binomial distribution after computing mean and variance.
- Fitting of Poisson distribution for given value of lambda.
- Fitting of Poisson distribution after computing mean.
- Fitting of exponential distribution.
- Fitting of normal distribution.
- Application problem based on binomial distribution.
- Application problem based on Poisson distribution.
- Application problem based on negative binomial distribution.

Reference Books

- Goon, A.M., Gupta, M.K. and Dasgupta,B. (2002): Fundamentals of Statistics, Vol.I & II,8thEdition, World Press, Kolkata.

- Miller, Irwin and Miller, Marylees(2006):John E.Freunds Mathematical Statistics with Applications,7thEdition, Pearson Education, Asia.
- Mood, A.M., Graybill, F.A. and Boes,D.C.(2007): Introduction to the Theory of Statistics, 3rd Edition,Tata McGraw-Hill Pub. Co. Ltd.
- Tukey, J.W.(1977): Exploratory Data Analysis, Addison-Wesley Publishing Co.
- Freedman, D., Pisani, R. and Purves, R.(2014): Statistics, 4thEdition, W. W. Norton & Company.
- Agresti, A. (2010): Analysis of Ordinal Categorical Data,2nd Edition, Wiley.
- Chung, K.L. (1983): Elementary Probability Theory with Stochastic Process, Springer/ Narosa.
- Feller, W.(1968): An Introduction to Probability Theory & its Applications, John Wiley.
- Goon, A.M., Gupta, M.K. & Dasgupta, B. (2003): An Outline of Statistical Theory Vol- I, World Press.
- Parzen, E.(1972):Modern Probability Theory and its Applications, John Wiley.
- Uspensky, J.V. (1937): Introduction to Mathematical Probability, McGraw Hill.
- Cacoullos, T.(1973):Exercises in Probability, Narosa.
- Ross, S. (2002): A First Course in Probability, Prentice Hall.
- Stirzaker, D.(2003): Elementary Probability, 2ndEdition, Cambridge University Press
- Rahman, N.A.(1983):Practical Exercises in Probability and Statistics, Griffin.
- Rohatgi, V.K. and Saleh, A.K.Md.E.(2009): An Introduction to Probability and Statistics. 2nd Edition, John Wiley and Sons.

STSHSE202M/STSGSE402M/STSGSE602M –Computation using Softwares

[Credit3] **[90 Lecture Hours]**

Unit1: Introduction to Excel [40 Lecture Hours]

Basic idea about software. Input and modification of data. Basic cell operations; operation of mathematical and inbuilt functions on cell. Display summary statisticsfor univariate and bivariate data. Regression and correlation computation. Use of Data Analysis' tool (only the applicable functions). Construction of data table andoperations onit.

Graphical representation of data: Column diagram, pie diagram, line diagram, bar diagram, scatterplot, boxplot, stock diagram, surface plot and radar plot, histogram.

Unit2: Introduction to R	**[50 Lecture Hours]**
Use of Rascal calculator. Operations within build mathematical functions. Input a vector, numeric and non-numeric vectors. Addition and deletion of data from a vector. Logical operations and use of different logical functions. Understanding the non-numeric outputs, like—NULL, NA and NaN. Array and Matrix with associated operations. Construction of new function in R. Use the help in R. Loading and installing packages in R.	
Reference Books	
• Davies, T.M. (2016): The Book of R: A First Course in Programming and Statistics,1st Edition, NoStarch Press, USA.	

SemesterIII

STSDSC303T–Mathematical Analysis I

[Credit5] **[75 Lecture Hours]**

Unit1: Background on Real Analysis **[18 Lecture Hours]**

Basic set theory; countability of a set and related results, countability of $\mathbb{Q}$; supremum and infimum of a set; Concept of function; equivalent set. Basic theorems on real numbers; Density property, Completeness property, Archimedeanproperty. Open set, closed set and compact set (closed and bounded).

Unit2: Sequence and Series of Real Numbers **[32 Lecture Hours]**

Sequence of real numbers and their convergence, limits of sequences, Cauchy'sgeneral principle of convergence, Cauchy's first theorem on limits, monotonic sequences, monotone convergence theorem of sequence, Squeeze theorem. Concept of subsequences, Bolzano-Weierstrass theorem. Limit superior and limitinferior of a bounded sequence, Cauchy's second theorem on limits. Infinite series, positive-termed series and their convergence. Comparison tests, Limit comparison test, D'Alembert's ratio test, Cauchy's n^{th} root test.
Absolute convergence of real series, Leibnitz's test for the convergence ofalternating series, conditional convergence.

Unit3: Properties of Real-valued Functions **[25 Lecture Hours]**

Limit, Continuity, Differentiability, Uniform continuity and Boundedness offunctions, Intermediate value theorem, Indeterminate forms, L'Hospital's rule. Rolle's Theorem and Lagrange's Mean Value Theorems (without proof). Taylor's Theorem with Lagrange's and Cauchy's form of remainder (without proof). Taylor's series expansion.

Reference Books

- Bartle, R.G. and Sherbert, D.R. (2011): Introduction to Real Analysis, John Wiley & Sons, Inc.
- Apostol, T. M. (1974): Mathematical Analysis, World Student Series Edition
- Kumar, A. and Kumaresana, S. (2014): Basic Course inRealAnalysis, Taylor & Francis Group, LLC
- Thomson, B.S., Bruckner, J.B. and Bruckner, A.M. (2001): Elementary Real Analysis, Prentice-Hall, Inc.
- Rădulescu, T-L.T., Rădulescu, V and Andreescu, T. (2009): Problems in Real Analysis, Springer Science+Business Media, LLC
- Trench, W.F. (2003): Introduction to Real Analysis, Prentice Hall
- Abbott, S. (2012). Understanding Analysis. Springer New York.

Semester-IV

STSDSC404T–Vector and Matrix Algebra

[Credit3] **[45 Lecture Hours]**

Unit1: Vector & Matrix **[25 Lecture Hours]**

Vector and vector spaces: Vectors defined on Euclidean space, definition of null-vector, unit vector, sum and inner product of two vectors, linear dependence and independence of vectors, spanning set, basis and dimension of a subspace, norm of a vector, orthogonal and orthonormal vectors. Gram-Schmidt orthogonalization. Concept of vector space, vector subspace, sum and direct sum of subspaces, projection of a vector on subspace. Orthogonal complement and orthogonal projection.

Matrix and matrix algebra: Basic matrix operations, Different types of matrices, orthogonal matrix and trace of a matrix. Elementary operations and elementary matrices. Matrix transformation, Determinant and its properties, evaluation of determinants. Non-singular matrix and inverse of a non-singular matrix. Partitioned matrix, its determinant and inverse.

Unit2: Rank of Matrix **[20 Lecture Hours]**

Rank of a matrix: Row-rank, column rank and rank of a matrix, echelon matrix and rank determination, rank inequalities, rank factorization. Null space and nullity of a matrix, Sylvester's and Frobenius inequality. Idempotent matrix and projector.

Solution of equation and elementary concept of g-inverse of a matrix: Condition for consistency of a system of equations.

STSDSC404P: List of Practicals

[Credit2] **[60 Lecture Hours]**

- Problems on independent and dependent set of vectors.
- Problems on spanning set and basis.
- Problems on Gram-Schmidt orthogonalization.
- Problems on rank of a matrix.
- Problems on inverse of a matrix.
- Problems on system of linear equations.

Reference Books

- Hadley G. (2002): Linear Algebra. Narosa Publishing House (Reprint)
- Searle S.R. (1982): Matrix Algebra Useful for Statistics. John Wiley &Sons
- Fienberg, S. H., Insel, A. J. and Spence, L. E. (2017): Linear Algebra (4th De.), Pearson
- Rao, A. R. and Bhimasankaram, P. (2000): Linear Algebra. Hindustan Book Agency
- Narayan Shanti (2004): A Textbook of Matrices, S Chand & Co Ltd.
- Apostol, T. M. (2002): Mathematical Analysis, Narosa Publishing House

STSDSC405T–Sampling Distribution & Statistical Inference I

[Credit 3] **[45 Lecture Hours]**

Unit 1: Sampling Distribution **[20 Lecture Hours]**

Distribution of functions of random variables (using transformation), reproductive properties, illustration through standard discrete and continuous distributions. Definition and derivation of Chi-square distribution, t-distribution, and F-distribution; nature of p.d.f. curve for different degrees of freedom, mean, variance, m.g.f., property and limiting distribution of Chi-square and t-distribution. Student's, Fishers and paired t-distributions. Sampling distribution of sample correlation coefficient and sample regression coefficient while sampling from bivariate normal distribution. Sampling distribution of least square estimates of the coefficients of simple linear regression model under normality. Ordered Statistics.

Unit 2: Unbiasedness **[8 Lecture Hours]**

Elementary concepts: Family of distributions, labelling parameter, parametric space, random sample, statistic, equivalent statistic, estimator and estimate, mean square error. Unbiased estimator and its properties, standard error. Exponential Family of distributions (one and multi-parameter), illustration through examples.

Unit 3: Best Choice of Estimator **[17 Lecture Hours]**

Sufficiency, Factorization theorem, minimal sufficiency, finding of minimal sufficient statistic due to Lehmann & Scheffe (1950) and associate results. Completeness, complete-sufficient statistic, role of exponential family of distribution in finding complete-sufficient statistic. Ancillary statistic, examples, Basu's theorem. UMVUE, Cramer-Rao Inequality, equality case, Cramer-Rao Lower Bound. Fisher information contained in a statistic, efficient estimator, Bhattacharyya Bounds, relative efficiency of estimators and results on UMVUE. Rao-Blackwell theorem and Lehmann-Scheffé theorem.

Method of moment estimation, Maximum likelihood estimation, properties and examples.

STSDSC405P: List of Practicals

[Credit 2] **[60 Lecture Hours]**

- Real life based practical problems on sampling distribution.
- Real life based practical problems on ordered statistics.
- Problems on finding of unbiased estimators of different parametric functions from known and unknown theoretical distributions.
- Problems on finding relative efficiencies of two unbiased estimators of a parametric function.
- Problems on finding of UMVUE of different parametric functions from known and unknown theoretical distributions.
- Problems on maximum likelihood estimation.

Reference Books

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): An Outline of Statistical Theory, Vol. I& II, World Press, Kolkata
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2001): Fundamental of Statistics, Vol. I, World Press, Kolkata
- Rohatgi, V.K. and Saleh, A.K.Md.E. (2009): An Introduction to Probability and Statistics. 2nd Edn. (Reprint), John Wiley and Sons
- Mood, A.M, Graybill, F.A. and Boes, D.C. (1974): Introduction to the Theory of Statistics, McGraw Hill
- Bhat, B.R, Srivenkatramana, T. and Rao, Madhava K. S. (1997): Statistics: A Beginner's Text, Vol. I, New Age International (P) Ltd.
- Casella, G. and Berger, R.L. (2002): Statistical Inference, 2nd Edn., Thomson Learning
- Lehman, E.L. and Casella, G. (1998): Theory of Point Estimation, 2nd Edn., Springer-Verlag New York, Inc.
- Ferguson, T.S. (1973). Mathematical Statistics. United States: Academic Press
- Li, B. and Babu, G.J. (2019): A Graduate Course on Statistical Inference, Springer Science + Business Media, LLC
- Mukhopadhyay, N. (2000): Probability and Statistical Inference, Marcel Dekker, Inc., New York
- Mukhopadhyay, P. (1996): Mathematical Statistics, New Central Book Agency, India

STSDSC406T –Probability Theory III

[Credit3] **[45 Lecture Hours]**

Unit1: Moments and Inequalities **[8 Lecture Hours]**

p.d.f. and c.d.f., illustrations and properties, univariate transformations through c.d.f. with illustrations. Derivation of moments. Probability Inequalities: Markov and Chebyshev.

Unit2: Generating Functions **[10 Lecture Hours]**

Probability generating function, moment generating function, cumulant generating function and characteristic function. Uniqueness and inversion theorems (without proof) along with applications.

Unit3: Standard Univariate Discrete and Continuous Probability Distributions-II & Bivariate Distributions **[27 Lecture Hours]**

Univariate Discrete un distributions-II: Geometric, Negative binomial and Hypergeometric. Univariate Continuous distributions II: Cauchy, beta, gamma, lognormal, logistic, double and Pareto along with their properties and limiting/approximation cases.

Discrete two-dimensional random variable: joint, marginal and conditional, p.m.f. and c.d.f., statement of properties of c.d.f., independence of variables, trinomial distribution. Continuous two-dimensional random variable: joint, marginal and conditional, p.d.f., and c.d.f. Independence of two random variables, bivariate transformations with illustrations. Moments. Conditional expectation and Conditional variance. Correlation coefficient. Bivariate Normal Distribution and its mgf and properties.

STSDSC406P: List of Practicals

[Credit2] **[60 Lecture Hours]**

- Fitting of univariate discrete distributions.
- Fitting of univariate continuous distributions.

ReferenceBooks

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): An Outline of Statistical Theory, Vol. I & II, World Press, Kolkata
- Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi
- Hoel P.G., Port, S. and Stone, C. (1972): Introduction to Probability Theory, Houghton Miffin
- Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia
- S.M. Ross: A First Course in Probability
- K.L. Chung: Elementary Probability Theory with Stochastic Process
- Mukhopadhyay, P. (1996): Mathematical Statistics. New Central Book Agency

STSDSC407T –Survey Sampling

[Credit3] **[45 Lecture Hours]**

Unit1: Simple Random Sample **[15 Lecture Hours]**

Concept of population and sample, complete enumeration versus sampling, sampling and non- sampling errors. Types of sampling: non-probability and probability sampling, basic principles of sample survey, simple random sampling with and without replacement, definition and procedure of selecting a sample, estimates of population mean, total and proportion, variances of these estimates, estimates of their variances and sample size determination.

Simple Random sampling using auxiliary information: Ratio and Regression methods of estimation.

Unit2: Stratified and Systematic Sampling **[18 Lecture Hours]**

Stratified random sampling, technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. Practical difficulties in allocation, estimation of gain in precision.

Systematic Sampling, Technique, estimates of population mean and total, variances of these estimates (N=n x k case). Comparison of systematic sampling with SRS and stratified sampling in the presence of linear trend and corrections.

Unit3: Other Sampling Methods **[12 Lecture Hours]**

Cluster sampling (equal-size clusters only) estimation of population mean and its variance, Concept of sub-sampling. Two-stage sampling, Estimation of Population mean and variance of the estimate, comparison between two-stage, cluster and uni-stage sampling. Randomized response technique: Warner's method.

STSDSC407P: List of Practicals
[Credit2] **[60 Lecture Hours]**

- Select an SRS with and without replacement.
- For a population of size 5, estimate population mean, population mean square and population variance. Enumerate all possible samples of size 2 by WR and WOR and establish all properties relative to SRS.
- For SRSWOR, estimate mean, standard error, the sample size
- Ratio and Regression estimation: Calculate the population mean or total of the population. Calculate mean squares. Compare the efficiencies of ratio and regression estimators relative to SRS.
- Stratified Sampling: allocation of sample to strata by proportional and Neyman's methods. Compare the efficiencies of above two methods relative to SRS.
- Estimation of gain in precision in stratified sampling.
- Comparison of systematic with stratified sampling and SRS in the presence of a linear trend.
- Cluster sampling: estimation of mean or total, variance of the estimate, estimate of intra-class correlation coefficient, efficiency as compared to SRS.
- Two stage sampling.

Reference Books

- Cochran, W.G. (1984): Sampling Techniques (3rd Ed.), Wiley Eastern
- Sukhatme, P.V., Sukhatme, B.V. Sukhatme, S. (1984). Sampling Theories of Survey with Application, IOWA State University Press and Indian Society of Agricultural Statistics
- Murthy, M.N. (1977): Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta
- Des Raj and Chandhok P. (1998): Sample Survey Theory, Narosa PublishingHouse
- Goon A.M., Gupta M.K. and Dasgupta B. (2008): Fundamentals of Statistics, Vol-2, World Press

SemesterV

STSDSC508T –Statistical Inference-II

[Credit 3] **[45 Lecture Hours]**

Unit 1: Introduction to Hypothesis Testing **[15 Lecture Hours]**

Elements of hypothesis testing: Null and alternative hypotheses, simple & composite hypotheses, critical region, type I and type II errors, level of significance, size, power, *p*-value. Exact tests: classical and *p*-value approaches, related confidence intervals. Tests of significance related to Binomial proportion(s), Poisson mean(s), Univariate Normal mean(s), standard deviation(s) and Bivariate normal parameters. Combination of probabilities in tests of significance.

Unit 2: Construction of Tests **[20 Lecture Hours]**

Theory of hypothesis testing: Test function, randomized and non-randomized tests, most powerful (MP) test, uniformly most powerful (UMP) test, Fundamental Neyman-Pearson Lemma and its applications to construct MP and UMP tests.
Likelihood ratio tests, properties of likelihood ratio tests (without proof).

Unit 3: Confidence Interval and Sequential Analysis **[10 Lecture Hours]**

Interval Estimation: Confidence intervals, Concepts of Uniformly Most Accurate (UMA) confidence sets, Uniformly Most Accurate Unbiased (UMAU) confidence sets, relationship with tests of hypotheses.
Sequential Analysis: Stopping variables, Sequential Tests, Wald's equation for ASN, SPRT and its properties –fundamental identity, OC and ASN.

STSDSC508P: List of Practicals
[Credit 2] **[60 Lecture Hours]**

- Test of significance for single proportion and difference of two proportions.
- Test of significance for single Poisson mean and difference of two Poisson means.
- Test of significance and confidence intervals for single mean and difference of two means.
- Test of significance and confidence intervals for single variance and ratio of two variances.
- Test of parameters under bivariate normal distribution.
- Type I and Type II errors.
- Most powerful critical region.
- Uniformly most powerful critical region.
- Power curves.
- Likelihood ratio tests for simple null hypothesis against simple alternative hypothesis.
- Likelihood ratio tests for simple null hypothesis against composite alternative hypothesis.
- Confidence intervals, UMA confidence sets and UMAU confidence sets.
- Problems related to sequential testing procedure.

Reference Books

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): An Outline of Statistical Theory, Vol. I& II, World Press, Kolkata
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2001): Fundamental of Statistics, Vol. I, World Press, Kolkata
- Rohatgi, V.K. and Saleh, A.K. Md.E. (2009): An Introduction to Probability and Statistics. 2nd Edn. (Reprint), John Wiley and Sons
- Mood, A.M, Graybill, F.A. and Boes, D.C. (1974): Introduction to the Theory of Statistics, McGraw Hill
- Bhat, B.R, Srivenkatramana, T. and Rao, Madhava K. S. (1997): Statistics: A Beginner's Text, Vol. I, New Age International (P) Ltd.
- Casella, G. and Berger, R.L. (2002): Statistical Inference, 2nd Edn., Thomson Learning
- Lehman, E.L. and Romano, J.P. (2005): Testing Statistical Hypotheses, 3rd Edn., Springer Science + Business Media, LLC
- Ferguson, T.S. (1973). Mathematical Statistics. United States: Academic Press
- Li, B. and Babu, G.J. (2019): A Graduate Course on Statistical Inference, Springer Science + Business Media, LLC
- Mukhopadhyay, N. (2000): Probability and Statistical Inference, Marcel Dekker, Inc., New York
- Mukhopadhyay, P. (1996): Mathematical Statistics, New Central Book Agency, India

STSDSC509T –Linear Models

[Credit 3] **[45 Lecture Hours]**

Unit 1: Basics of Linear Modeling **[10 Lecture Hours]**

General objectives of model building: inference and prediction, difference between parametric and nonparametric approaches. Review of simple linear regression and its properties, extension of linear regression: polynomial regression, multiple regression. General Linear Model: introduction and examples, use of dummy variables, different types of linear models and their parameter interpretations.

Unit 2: Gauss-Markov set-up **[15 Lecture Hours]**

Theory of linear estimation, estimability of linear parametric functions, method of least squares, Gauss-Markov Theorem, estimation space and error space, estimation of error variance. Fundamental theorems on least squares (statements only). Tests of General Linear Hypotheses (statements only). Classification of linear models.

Unit 3: Regression model and its diagnostic checking **[20 Lecture Hours]**

Fitting of multiple regression model. Model accuracy checking: Checking the linear relation between study and explanatory variables, residual analysis-standardized residual, Studentized residual, PRESS residuals, R-student, residual plot. Normal probability plot. Partial regression and partial residual plot. Outlier detection based on R-student. Diagnostics of leverage and influence, leverage point, measure of influence- Cook's D-statistics, DEFFITS and DEBETAS, transformation to linearize

the model: Box-Cox and Box-Tidwell transformation. Adjusted R square, Mallow's CP, AIC, AICc.

STSDSC509P: List of Practicals
[Credit 2] [60 Lecture Hours]

- Estimability in Gauss Markov Model.
- Simple linear regression.
- Multiple regression using Gauss-Markov model.
- Tests for linear hypothesis.
- Regression Diagnostic checking .

Reference Books

- Goon, A.M., Gupta, M.K., and Dasgupta, B. (2002), Fundamental of Statistics, Volume 2, 8th Edn. The World Press, Kolkata.
- Scheffe, H, Linear Models
- Sengupta, D. and Jammalamadaka, S. R. (2020), Linear Models and Regression with R. World Scientific Publisher.
- Rao, C.R., Linear Statistical Inference.
- Mukhopadhyay, P. (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied(P) Ltd.
- Weisburg, S (2005) Applied Linear Regression (Third edition), Wiley.
- Renchner, A.C. and Schaalje, G.B. (2008). Linear Models in Statistics (Second edition), John Wiley and Sons.

STSDSC510T–Mathematical Analysis II and Linear Algebra II
[Credit5] [75 Lecture Hours]

Unit1: Eigen values and Quadratic form [18 Lecture Hours]

Eigenvalues and eigenvectors: Definition of eigenvalues and eigenvectors. Matrix polynomial, Caley Hamilton theorem and its application. Eigenspace, geometric and algebraic multiplicity of eigenvalues. Spectral decomposition theorem with application.

Quadratic form: Quadratic form and its classification, important properties of positive definite and non-negative definite matrix. Diagonalization of quadratic form. Extrema of quadratic form.

Unit2: Riemann and Improper Integral [15 Lecture Hours]

Reimann Integration of Real-valued Functions, Darboux approach. Improperintegrals, convergence of integrals, simple tests, beta and gamma integral.

Unit3: Sequence and Series of Functions [22 Lecture Hours]

Sequence and series of functions, pointwise and uniform convergences. Simple tests, Weierstrass M-test. Power series, radius and interval of convergence, basic properties of power series.

Unit4: Functions of Several Variables	**[20 Lecture Hours]**
Functions on several variables, constrain optimization using Lagrange's multipliers. Double and multiple integrals, Fubini's theorem, change of variables, concept of Jacobian.	

Reference Books

- Bartle, R.G. and Sherbert, D.R. (2011): Introduction to Real Analysis, John Wiley & Sons, Inc.
- Apostol, T. M. (1974): Mathematical Analysis, World Student Series Edition
- Kumar, A. and Kumaresana, S. (2014): Basic Course in Real Analysis, Taylor & Francis Group, LLC
- Thomson, B.S., Bruckner, J.B. and Bruckner, A.M. (2001): Elementary Real Analysis, Prentice-Hall, Inc.
- Rădulescu, T-L.T., Rădulescu, V and Andreescu, T. (2009):Problems in Real Analysis, Springer Science + Business Media, LLC
- Trench, W.F. (2003): Introduction to Real Analysis, Prentice Hall
- Abbott, S. (2012): Understanding Analysis. Springer New York
- Athreya, K. B., Lahiri, S. N. (2006): Measure Theory and Probability Theory, Springer
- Ash, R. B., Doleans-Dade, C. A. (2000): Probability and measure theory, Elsevier Science
- Billingsley, P. (2017): Probability and Measure, Wiley India
- Basu, a. K. (2012): Measure Theory and Probability, PHI learning, India
- Capinski, M., Kopp, P. E. (2004): Measure, Integral and Probability, Springer London, Germany

STSDSC511T – Statistical Quality Control

[Credit 3] **[45 Lecture Hours]**

Unit 1: Quality and Control Chart	**[20 Lecture Hours]**
Definition, dimensions of quality, historical perspective of quality control and improvements starting from World War II, historical perspective of Quality Gurus and Quality Hall of Fame. Quality system. X-bar & R-chart, X-bar & s-chart. Control charts for attributes: np-chart, p-chart, c-chart and u-chart. Comparison between control charts for variables and control charts for attributes. Analysis of patterns on control chart. Estimation of process capability.	
Unit 2: Sampling Inspection Plan for Attributes	**[15 Lecture Hours]**
Principle of acceptance sampling plans. Single and Double sampling plan their OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with graphical interpretation, use and interpretation of Dodge and Romig's sampling inspection plan tables.	
Unit 3: Introduction to Six Sigma	**[10 Lecture Hours]**

Overview of Six Sigma, Lean Manufacturing and Total Quality Management (TQM). Organizational Structure and Six Sigma training plans- Selection Criteria for Six-Sigma roles and training plans. Voice of customers (VOC): Importance and VOC data collection. Critical to Quality (CTQ). Introduction to DMAIC using one case study: Define Phase, Measure Phase, Analyse Phase, ImprovePhase and Control Phase.

STSDSC511P: List of Practicals
[Credit 2] [60 Lecture Hours]

- Construction and Interpretation of statistical control charts: X bar and R chart
- X-bar & s-chart,np- chart
- p-chart c-chart u- chart
- Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD,ASN, ATI, AOQ, AOQL curves.
- Calculation of process capability and comparison of 3-sigma control limits with specification limits.
- Use a case study to apply the concept of six sigma application in DMAIC: practical application.

Reference Books

- Montgomery, D.C. (2009): Introduction to Statistical Quality control, 6th edition, Wiley India,Pvt Ltd
- Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol 2, 8thedition, The world Press, Kolkata
- Mukhopadhyay, P. (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied(P)Ltd.
- Montgomery, D.C. and Runger, G.C. (2008): Applied Statistics and Probability forEngineers, 3rd edition reprint, Wiley India Pvt Ltd.
- Ehrlich, B. Harris (2002): Transactional Six sigma and Lean Servicing, 2nd edition, St LuciePress
- Hoyle, David (1995): ISO Quality systems Handbook, 2nd edition, Butterworth Heinemann Publication.

Semester-VI

STSDSC612T – Stochastic Processes and Time Series Analysis

[Credit 3] **[45 Lecture Hours]**

Unit 1: Time Series Data **[15 Lecture Hours]**

Introduction to time series data and application of time series from various fields. Components of a time series (trend, cyclical and seasonal patterns, random error). Estimation of trend by free hand curve method, method of semi averages, method of moving averages, fitting various mathematical curves and growth curves. Effect of elimination of trend on other components of the time series. Estimation of seasonal component by method of simple averages, ratio to trend, ratio to moving average and link relative method. Variate difference method.

Unit 2: Stochastic Processes **[10 Lecture Hours]**

Introduction of stochastic process and stationary process.
Markov Chains: Definition of Markov Chain, examples including 2-state chain, random walk, etc. Transition probability matrix, higher order transition probabilities, order of a Markov chain, Markov chain as graphs, classification of states of a Markov Chain.

Unit 3: Time Series Model, Estimation and Forecasting **[20 Lecture Hours]**

Time Series as a Stochastic Process. Stationary time series - weak stationarity, autocorrelation function and correlogram. Some special processes: Moving-average (MA) process and Autoregressive (AR) process of orders one and two. ACF, PACF and their graphical use in guessing the order of AR and MA processes. Estimation of the parameters of AR (1) and AR (2) – Yule-Walker equations. Introduction to ARMA and ARIMA models. Forecasting: Exponential smoothing methods.

STSDSC612P: List of Practicals
[Credit 2] **[60 Lecture Hours]**

- Calculation of transition probability matrix, Identification of characteristics of reducible and irreducible chains, Identification of types of classes, Identification of ergodic transition probability matrix, Stationarity of Markov chain.
- Plotting a real time series, and detecting various features (trend, periodic behaviours etc.).
- Determination of trend by (i) Moving Average Method, ii) curve fitting and plotting de-trended series
- Determination of seasonal indices by (i) ratio to trend method, (ii) ratio to moving average method and (iii)method of link relatives
- Correlogram Analysis
- Plotting ACF of a given time series.
- Fitting of AR 1 and AR 2 models
- Forecasting by Exponential Smoothing

Reference Books

- Hoel, P.G.; Port, S.C. and Stone, C.J. (1986): Introduction to Stochastic Processes, Waveland Pr.
- Medhi, J. (2009): Stochastic Processes, New Age International Publishers.
- Ross, S.M. (2008): Stochastic Processes, Second Edition, Wiley Publisher.
- Bhat, B.R. (2000): Stochastic Models: Analysis and Applications, New Age International Publishers.
- R. N. Bhattacharya and Waymire, E.C. (2009): Stochastic Process and Applications, SIAM Classics Ed.
- Gun, Gupta and Dasgupta (2002): Fundamentals of Statistics, Vol. II, World Press.
- Cooray, TMJA (2008): Applied Time Series, Analysis and Forecasting, Narosa Publishing House.
- Chatfield, C. (2004): Analysis of Time Series, Chapman & Hall.
- Brockwell, P. and Davis, D. (2016): Introduction to Time Series and Forecasting, 3rd Ed., Springer.

STSDSC613T – Large Sample Theory

[Credit 3] **[45 Lecture Hours]**

Unit 1: Limit Theorems **[18 Lecture Hours]**

Convergence in probability, convergence in distribution, Convergence in r^{th} mean, almost sure convergence, relation between these of convergences, associate theorems. Weak Laws of Large Numbers (WLLN), Strong Laws of Large Numbers (SLLN) and their applications. Khinchini's WLLN, Kolmogorov's SLLN (without proof). Slutsky's theorem. De Moivre-Laplace central limit theorem (CLT). Lindeberg-Lévy CLT (with proof).

Unit 2: Standard Errors of Statistics and Variance Stabilization **[12 Lecture Hours]**

Delta method and Cramér-Wold device. Derivation and uses of large sample standard error of sample moments, standard deviation, coefficient of variation, g_1&g_2 measures, correlation coefficient, regression coefficient, asymptotic distribution ofsample quantiles. Variance stabilizing transformation of Statistic, Derivation of$\sin^{-1}$, square root, logarithmic & Fisher's Z transformations and associated applications.

Unit 3: Asymptotic Properties and Pearsonian χ^2 **[15 Lecture Hours]**

Consistency, asymptotic efficiency, ARE, CAN and BAN estimators. Asymptotic properties of MLE (statement only) and their uses in testing and confidence interval.

Large sample distribution of Pearsonian χ^2 statistic, its uses (goodness of fit, independence and homogeneity). Yates' correction in a 2×2 contingency table. Fisher's exact test in 2×2 contingency table.

STSDSC613P: List of Practical

[Credit 2] **[60 Lecture Hours]**

- Tests of significance and confidence intervals for single proportion and difference of two Binomial proportions using CLT.
- Tests of significance and confidence intervals for single Poisson mean and difference oftwo Poisson means using CLT.
- Tests of significance and confidence intervals concerning sample standard deviation, coefficient of variation and correlation coefficient (both single sample, two sample cases).
- Tests of significance and confidence intervals using variance stabilizing transformations.
- Determination of the minimum sample size required to achieve normality by sampleproportion, mean, standard deviationand correlation coefficient using CLT and variance stabilizing transformations.
- Tests for goodness of fit, independence and homogeneity using Pearsonian chi-square statistic.
- Test based on Fisher's exact test.

Reference Books

- Goon, A.M., Gupta, M.K. & Dasgupta, B. (2005): An Outline of Statistical Theory Vol- I & II, World Press
- Rohatgi, V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2nd Edition, John Wiley and Sons
- Li, B. and Babu, G.J. (2019): A Graduate Course on Statistical Inference, Springer Science+Business Media, LLC
- Ferguson, T.S (1996): A Course in Large SampleTheory, Springer Science+Business Media Dordrecht
- Jiang, J. (2010): Large Sample Techniquesfor Statistics, Springer Science+Business Media, LLC
- DasGupta, A (2008): Asymptotic Theoryof Statistics and Probability, Springer Science+Business Media, LLC
- Lehmann, E.L. (1999): Elements ofLarge-Sample Theory, Springer-Verlag New York, Inc.

STSDSC614T – Demography

[Credit 3] **[45 Lecture Hours]**

Unit 1: Introduction and Measures of Mortality **[20 Lecture Hours]**

Demographic events and processes. Sources of population data, Census and registration. Errors incensus and registration data. Rates and ratios of vital events. Crude death rate (CDR), Specific death rate (SDR), Infant mortality rate (IMR) and Standardized death rates. Life (Mortality) tables: assumption, description and uses. Stable and Stationary population.

Unit 2: Measures of Fertility **[13 Lecture Hours]**

Crude Birth Rate (CBR), General Fertility rate (GFR), Specific Fertility rate (SFR) and total Fertility rate (TFR). Measurement of population growth: Crude rates of natural increase, Pearl's Vital index, Gross Reproduction Rate (GRR) and Net reproduction rate (NRR).

Unit 3: Estimation **[12 Lecture Hours]**

Population estimation, Projection and Forecasting: Use of AP and GP methods for population estimates. Fitting of population curve for population forecasting using Rhode's method.

STSDSC614P: List of Practical

[Credit 2] **[60 Lecture Hours]**

- Computation of Crude Birth Rate
- Computation of different Fertility Rates
- Computation of Vital Index, Reproduction Rates
- Fitting of population curve for population forecasting including Rhodes method
- Computation of different mortality rates and Makeham's Graduation formula
- Preparation of Life Table

Reference Books

- Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol 2, 8th edition, The world Press, Kolkata
- Mukhopadhyay, P. (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied (P) Ltd.

STSDSC615T –Multivariate Analysis & Nonparametric Inference

[Credit 3] **[45 Lecture Hours]**

Unit 1: Introduction to Random Vector **[12 Lecture Hours]**

Random Vector: Probability mass/density functions, Distribution function, Mean vector and Dispersion matrix, Marginal and Conditional distributions.

Unit 2: Multivariate Distributions and Applications **[15 Lecture Hours]**

Multinomial Distribution, Multivariate Normal distribution and its properties. Sampling distribution for mean vector and variance-covariance matrix (Statement

only). Multiple and partial correlation coefficients and their properties.
Population principal components, principal components obtained from standardized variables, principal components for covariance matrix with special structures. Summarizing sample variation by principal components, the number of principal components, interpretation of sample principal components.

Unit 3: Nonparametric Inference **[18 Lecture Hours]**

Nonparametric Tests: Introduction and concept, nonparametric location problem and scale problem, simple linear rank statistics, score functions, test for randomness based on total number of runs, empirical distribution function, Kolmogorov Smirnov test for one sample and two samples, Sign tests one sample and two samples, Signed rank test, Wilcoxon rank sum test, Mann Whitney test, Median test, Bivariate Sign test, Kruskal Wallis test.

STSDSC615P: List of Practicals
[Credit 2] **[60 Lecture Hours]**

- Problems on multiple correlation.
- Problems on partial correlation.
- Problems on multinomial distribution.
- Problems on multivariate normal distribution.
- Problems on principal components analysis.
- Problems on test for randomness based on total number of runs.
- Problems on Kolmogorov Smirnov test for one sample and two samples.
- Problems on Sign test: one sample, two samples, and large sample.
- Problems on Wilcoxon rank sum test, Mann Whitney test and median test.
- Problems on Kruskal Wallis test.

Reference Books

- Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rd Edn., John Wiley
- Muirhead, R. J. (1982): Aspects of Multivariate Statistical Theory, John Wiley
- Kshirsagar, A.M. (1972): Multivariate Analysis, 1st Edn. Marcel Dekker
- Johnson, R.A. and Wichern, D.W. (2007): Applied Multivariate Analysis, 6th Edn., Pearson & Prentice Hall
- Mukhopadhyay, P. (1996): Mathematical Statistics
- Gibbons, J. D. and Chakraborty, S (2003): Nonparametric Statistical Inference. 4th Edn., Marcel Dekker, CRC
- Kotz, S., Nadarajah, S. (2004): Multivariate t-Distributions and Their Applications, Cambridge University Press, United Kingdom
- Mukhopadhyay, P. (2009). Multivariate Statistical Analysis, World Scientific, Singapore

Semester-VII

STSDSC716T –Design of Experiments

[Credit 3] **[45 Lecture Hours]**

Unit 1: Analyses of Variance and Covariance **[15 Lecture Hours]**

Hypothesis testing in the case of simple and multiple regression models. Tests for parallelism and identity, linearity in regression models.
Analysis of Variance in one-way and two-way classified data (with equal number of observations per cell) for fixed, random, and mixed-effect models. Analysis of covariance for one-way and two-way classified data with one concomitant variable.

Unit 2: Experimental Designs and Models **[15 Lecture Hours]**

Experimental designs: role and historical perspective. Terminologies: experimental unit. Basic principles, uniformity trials, fertility contour maps, choice of size and shape of plots and blocks. Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – layout, model, treatment contrast and analysis, relative efficiencies, analysis with one missing observation. Orthogonal Latin Square Design.

Unit 3: Factorial Experiments **[15 Lecture Hours]**

Advantages, notations and concepts of 2^n factorial experiments - their design and analyses. Total and partial confounding for 2^n $(n \leq 5)$, factorial experiments.
Construction of one-half and one-quarter fractions of 2^n $(n \leq 5)$ factorial experiments.

STSDSC716P: List of Practicals
[Credit 2] [60 Lecture Hours]

- Analysis of Regression
- Analysis of Variance
- Analysis of Covariance
- Analysis of CRD
- Analysis of an RBD
- Analysis of an LSD
- Analysis of an RBD with one missing observation
- Analysis of an LSD with one missing observation
- Analysis of 2^2 and 2^3 factorial in CRD and RBD
- Analysis of 2^2 and 2^3 factorial in LSD
- Analysis of a completely confounded two level factorial design in 2 blocks
- Analysis of a completely confounded two level factorial design in 4 blocks
- Analysis of a partially confounded two level factorial design

Reference Books

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics, Vol. II, 8thEdn. World Press, Kolkata
- Mukhopadhyay, P. : Applied Statistics
- Cochran, W.G. and Cox, G.M. (1959): Experimental Design. Asia Publishing House
- Dey, A. (1986): Theory of Block Designs, Wiley Eastern Limited
- Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley
- Das, M.N. and Giri, N.C. (1986): Design and Analysis of Experiments. Wiley Eastern Ltd
- Kempthorne, O. (1965): The Design and Analysis of Experiments. John Wiley

STSDSC717T – Numerical Analysis and Statistical Computing

[Credit 3] **[45 Lecture Hours]**

Unit 1: Numerical Analysis **[20 Lecture Hours]**

Approximation of numbers and functions. Absolute and Relative errors. Interpolation: Polynomial approximation, Weierstrass Theorem (Statement). Difference Table, Newton's Forward and Backward interpolation formulae and Lagrange's general interpolation formula, Error terms. Numerical Integration: Trapezoidal and Simpson's 1/3rd rules. Numerical solution of equations: method of bisection method of iteration and Newton-Raphson method in one unknown, conditions of convergence (statement only).
Stirling's approximation to factorial n.

Unit 2: Statistical Computing **[25 Lecture Hours]**

Using the computer for random number generation (treated as a black box). A brief look at some popular approaches (no mathematical justification needed). Simulating a coin toss, a die roll and a card shuffle. CDF inversion method. Simulation from standard distributions. Finding probabilities and moments using simulation.
Monte Carlo integration. Basic idea of importance sampling. (MCMC not included).
Generating from Binomial and Poisson distributions, and comparing the histograms to the PMFs.
Generating from Uniform (0, 1) distribution, and applying inverse CDF transforms. Simulating Gaussian distribution using Box-Muller method. Approximating the expectation of a given function of a random variable using simulation. Graphical demonstration of the Law of Large Numbers. Approximating the value of pi by simulating dart throwing.
Resampling techniques: Cross validation, Jackknife and Bootstrap.
Formulation of the EM algorithm.

STSDSC717P: List of Practicals

[Credit 2] **[60 Lecture Hours]**

- Numerical methods: Interpolation by Lagrange's formula.
- Solving one variable equation using method of bisection.
- Solving one variable equation using Newton-Raphson method.
- Solving one variable equation using iteration method.
- Trapezoidal rule for numerical Integration.
- Simpson's1/3rd rule for numerical integration.
- Drawing random samples using inversion method.
- Drawing random samples from discrete distributions, mixture distributions.
- Estimation problems using cross validation, Jackknife and Bootstrap.
- Implementation of EM algorithms.

Reference Books

- Voss, J. (2013). An Introduction to Statistical Computing: A Simulation based Approach. Wiley.
- Good, P. I. (2013). Introduction to Statistics through Resampling Methods and R, Second edition. Wiley.
- Huber, P. J. and Ronchetti, E. M. (2009): Robust Statistics, Second Edition, Wiley.
- Ruppert, D, Wand, M. D. and Carroll, R. J. (2003): Semiparametric Regression, Cambridge Series in Statistical and Probabilistic Mathematics.
- McLachlan, G. J. and Krishnan, T. (2008): The EM Algorithm and Extensions, 2nd Edition, Wiley Inter science.

Semester-VIII

STSDSC818T– Economic Statistics and Official Statistics*

[Credit 3] **[45 Lecture Hours]**

Unit 1: Index Numbers and National accounts [20 Lecture Hours]

Index Numbers, price, quantity and value indices, choice of weights, Various formulae and their comparisons. Tests of index numbers. Fisher's ideal index number. Chain Index Number. ConsumerPrice Index, Wholesale Price index & Index of industrial Production- methods of construction and uses. Definition of national income. A brief account of product, expenditure and income approaches for estimation of National Income.

Unit 2: Measurement of poverty and inequality and Social Statistics [20 Lecture Hours]

Measurement of poverty and inequality, Desirable properties and different descriptive measures including Gini's coefficient, Lorenz curve. Use of Pareto and Log Normal distributions. Measures ofunemployment. Comparative Social Statistics, Indices related to human development and gender disparity.

Unit3: Official statistical [5 Lecture Hours]

Present official statistical system in India, Methods of collection of official statistics, their reliability and limitations. Role of Ministry of Statistics and Program Implementation (MoSPI).

STSDSC818P: List of Practicals
[Credit 2] **[60 Lecture Hours]**

- Price and quantity index numbers using simple and weighted average of price relatives.
- To calculate the Chain Base index numbers.
- Problems on cost of living index numbers.
- Lorenz curve.
- Pareto and lognormal fitting.

Reference Books

- Mudgett Bruce D (1951): Index Numbers, N.Y : Wiley.
- Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. II, 8thEdn. The World Press, Kolkata.
- Nagar A.L, Das R.K (1997): Basic statistics, Oxford University Press.
- Guide to current Indian Official Statistics, Central Statistical Office, GOI, and New Delhi.http://mospi.nic.in/

STSDSC819T–Discrete Data Analysis*

[Credit3] **[45 Lecture Hours]**

Unit 1: Analyzing Contingency Tables **[17 Lecture Hours]**

Measures of variability, Measures of association using variability, Simpson's paradox.
$k \times l$ contingency table: Pearson's chi-square and its modifications, Kendall's r and r_b, Goodman Kruskal's γ.

Unit2: Generalized Linear Model **[18 Lecture Hours]**

Generalized linear Model, Components of a generalized linear model, Random component, systematic component, Link function.
Generalized linear model for binary data, Logistic and probit regression model, Multiple logistic regression. Model fitting by using score function. Multicategory Logit models. Latent variable approach. Generalized linear model for count data, Poisson regression.

Unit3: Models for contingency table **[10 Lecture Hours]**

Log linear model of independence for two-way table, Interpretation of the parameters in independence model, saturated model for two-way table. The log-linear-logistic connection.

STSDSC819P: List of Practicals
[Credit2] **[60 Lecture Hours]**

- Practical using measures of association using variability.
- Fitting a logit model
- Fitting a probit model
- Fitting of multiple logistic regression.
- Fitting multi-category logistic regression.
- Fitting Poisson regression.
- Numerical problems form models for contingency table.

ReferenceBooks

- P.Mc Cullagh & J.A.Nelder.(1995):Generalized Linear Models. Chapmanand Hall.
- J.F. Simonoff: Analyzing Categorical Data.
- S.E. Fienberg: The Analysis of Cross Classified data
- MichaelS. Lewis Beck.: Basic Statistics.
- Agresti,A. (2007):An Introduction to Categorical data analysis. Wiley.

STSDSC820T – Financial Time Series Analysis*

[Credit 3] **[45 Lecture Hours]**

Unit 1: Non-stationary Financial Time Series Data[16 Lecture Hours]

Recapitulation of Stationary Time Series Analysis: Strongly and weekly Stationary processes, ergodicity, stationarity of time series and its importance in analysis, Wald Decomposition, Correlogram, ACF and PACF, AR, MA and ARMA model, Stationarity and invertibility conditions, fitting of AR, MA and ARMA processes, diagnostics checking for stationary processes, forecasting with these models.

Non-Stationary Time Series: Asset data over time and their preliminary graphical analysis, return and log-return data of a financial asset. Non-stationarity: random walk and other stochastic models. Types of non-stationarity - integrated time series and time series with stochastic trend. Test of stationarity - graphical method, correlogram, unit root test, Dickey-Fuller (DF) test, and Augmented DF test. ARMA family of models - ARIMA and Seasonal ARIMA modelling using Box-Jenkins approach.

Unit 2: Volatility, its Characteristics & Modelling [16 Lecture Hours]

Concept of volatility, volatility clustering, conditional heteroscedasticity. Volatility modelling and forecasting - ARCH, GARCH, E-GARCH models and their illustrative applications in real data and associated forecasting.

Unit 3: Asset Portfolio Risk Measure & CAPM [10 Lecture Hours]

Definition of risk, Value at Risk (VaR) as a quantile measure of risk, parametric and nonparametric approaches to VaR estimation. Expected Shortfall. Density forecasting of risk using ARCH models. Risk measure, real data applications. Capital asset pricing model (CAPM): share price, modern portfolio theory, CAPM modelling. Case studies with real-life financial data.

STSDSC820P: List of Practicals

[Credit 2] **[60 Lecture Hours]**

- Basic time series analysis, decomposition, ACF, PACF, ARMA model identification, fitting
- Forecasting using fitted ARMA model(s) and comparing the results with the forecasting using the Exponential Smoothing technique
- Analysis of Non-stationary Time Series data: applications of unit root test, DF and ADF tests, fitting and forecasting of ARIMA and SARIMA models
- Identification of the presence of volatility in a given dataset, applications of ARCH, GARCH models in the suitable data
- Black-Scholes Model: Applications to real data
- VaR estimation, measuring risk from real data
- CAPM: tests of CAPM

Reference Books

- Tsay, R.S. (2010): Analysis of Financial Time Series (3rd Ed.), John Wiley.
- Box, George E. P., Gwilym M. Jenkins, Gregory C. Reinsel, Greta M. Ljung. (2015). Time Series Analysis, Forecasting and Control, Wiley
- Brockwell & Davis (2016): Introduction to Time Series and Forecasting (3rd Ed.), Springer.
- Brooks, C. (2019): Introductory Econometrics for Finance (4th Ed.), Cambridge University Press.
- Chan, N.H. (2002): Time Series: Applications to Finance, Wiley
- Mills, T. C. (1999): The Econometric Modelling of Financial Time Series (2nd Ed.), CambridgeUniversity Press.

STSDSC821T– Introduction to Bayesian Inference*

[Credit 3] **[45 Lecture Hours]**

Unit 1: Introduction [25 Lecture Hours]

Elements of decision theory - Preliminary ideas of decision rules, loss and risk. Overview and comparison of two paradigms – Classical statistical analysis and Bayesian analysis. Relative advantages and disadvantages, motivation for choice of different priors.

Bayesian Inference – estimation, testing, interval estimation and prediction for some common models and common priors, Hierarchical Bayes, brief discussions on Bayesian computational techniques and their applications.

Unit 2: Applications [20 Lecture Hours]

Hierarchical Bayes, Hierarchical Bayesian shrinkage and Bayesian estimation, Empirical Bayes estimation (with examples), James-Stein estimator, Comparison of Hierarchical vs. Empirical Bayes.

STSDSC821P: List of Practicals

[Credit 2] **[60 Lecture Hours]**

- Problems on Bayesian estimation.
- Problems on Bayesian interval estimation.
- Problems on Bayesian model selection.
- Problems on Bayesian Monte Carlo and MCMC
- Related problems on other topics of Unit 1 – 2.

Reference Books

- Berger, J.O. (1985): Statistical Decision Theory and Bayesian Analysis, Springer New York
- Ghosh, J.K., Delampady, M. and Samanta, T. (2006): An Introduction to Bayesian Analysis: Theory and Methods, Springer New York
- Lee, P.M. (2012): Bayesian Statistics: An Introduction, Wiley, United Kingdom
- Robert, C. (2007): The Bayesian choice: From Decision-Theoretic Foundations to Computational Implementation, Springer, Ukraine

STSDSC822T– Econometrics*

[Credit 3] **[45 Lecture Hours]**

Unit 1: Introduction and Heteroscedasticity **[10 Lecture Hours]**

Comparing mathematical and econometric model with illustrative examples – consumption and production function. Stages of econometric methodology, Review of simple linear regression model.

Nature of heteroscedasticity – illustrative examples, OLS method under heteroscedasticity and its consequences, detecting heteroscedasticity – residual plot, Glejser test, Goldfeld-Quandt test, remedial measure through variable transformation and generalized least squares (GLS).

Unit 2: Autocorrelation **[15 Lecture Hours]**

Nature of autocorrelation – illustrative examples, OLS method under autocorrelation – AR(1) model, detecting autocorrelation – residual plot, Runs test, Durbin-Watson test, GLS method for correcting autocorrelation.

Unit 3: Multicollinearity **[20 Lecture Hours]**

Nature of multicollinearity – illustrative examples, OLS method under perfect multicollinearity and its consequences, detecting multicollinearity – thumb rules based on R^2, pair-wise and partial correlations, remedial measures via more data, dropping and transformation of variables.

STSDSC822P: List of Practicals

[Credit 2] **[60 Lecture Hours]**

- Fitting of ordinary linear regression equations with diagnostics.
- Tests of heteroscedasticity.
- Fitting of regression equation after making adjustments for heteroscedasticity.
- Tests of autocorrelation.
- Fitting of regression equation after making adjustments for autocorrelation.
- Tests of multicollinearity.
- Fitting of regression equation after making adjustments for multicollinearity.

Reference Books

- G.S. Maddala: Introduction to Econometrics
- D.N. Gujarati: Basic Econometrics
- J. Johnston and J. Dinardo: Econometric Methods

STSDSC823T – Survival Analysis and Clinical Trials*

[Credit 3] **[45 Lecture Hours]**

Unit 1: Preliminary Topics and censoring **[15 Lecture Hours]**

Survival Analysis: Functions of survival times, survival distributions and their applications: exponential, gamma, Weibull, lognormal, etc. Censoring Schemes: Type I, Type II and progressive or random censoring with biological examples. Estimation of mean survival time and variance of the estimator for Type I and Type II censored data with numerical examples. Survival function, Hazard Function and their relationship. Kaplan-Meier and Nelson-Aalen methods for estimating survival function and variance of the estimator.

Unit 2: Testing and model fitting **[15 Lecture Hours]**

Log rank test, Introduction to Cox Proportional Hazard (PH) regression, Model diagnostic checking, Accelerated failure time (AFT) model. Competing risk theory: Gray's test and Fine-Gray model.

Unit 3: Clinical Trials **[15 Lecture Hours]**

Clinical Trials: definition, ethics, masking and blinding, phases, Multicenter trials, objectives and endpoints of clinical trials, Randomized control trial. Dose-Response study, Discussions of different historical clinical trials.

STSDSC823P: List of Practicals
[Credit 2] **[60 Lecture Hours]**

- Fitting and plotting Kaplan-Meier estimator
- Performing log rank test
- Fitting Cox PH model and checking model diagnostics
- Fitting AFT model
- Performing Gray's test
- Fitting Fine-Gray model
- Problems for dose-response study

Reference Books

- Kalbfleisch J. D. and Prentice R. (1980): The Statistical Analysis of failure Time data, John Wiley.
- Kleinbaum, D.G. (1996): Survival Analysis, Springer
- Lee, Elisa, T. (1992). Statistical Methods for Survival Data Analysis, John Wiley & Sons.
- Miller, R.G. (1981). Survival Analysis, John Wiley & Sons.
- Piantadosi. S. (1997): Clinical Trials: A Methodologic Perspective. Wiley and Sons.
- Friedman, L. M. Furburg, C. Demets, D. L. (1998): Fundamentals of Clinical Trials. Springer Verlag.
- Marubeni. E. and Valsecchi. M. G. (1994): Analyzing Survival Data from Clinical Trials and Observational Studies, Wiley and Sons.

STSDSC823P – Research Project Dissertation** **[Credit 15]**
• A students selected for 4-year Honours with Research programme is required to complete a research project and submit a dissertation to the University for examination and evaluation in this semester. • The aim of the course is to initiate students to write and present a statistical report,under the supervision of a faculty, on some area of human interest. • The project work will provide hands on training to the students to deal with data emanating from some real life situation and propel them to dwell on some theory orrelate it to some theoretical concepts.

**** The department offer the required number of course(s) to the students among the six courses in Semester VIII subject to the availability of infrastructure of a college. Also the paper(s) to be offered will be announced before commencement of a semester.***

***** A student opted the Research Project Dissertation in semester VIII has to take ONE DSC paper from the set of available and offered courses STSDSC818T to STSDSC823T.***