

**Learning Outcomes based Curriculum Framework
(LOCF)
for
Statistics
Undergraduate Programme B.Sc. (Honors)
2019**



**UNIVERSITY GRANTS COMMISSION
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NEW DELHI – 110 002**

Foreword

UGC has been taking several initiatives for quality improvement in higher education system in the country. Curriculum revision is one of the focus areas of these initiatives. Curriculum development is defined as planned, a purposeful, progressive, and systematic process to create positive improvements in the higher educational system. The ever evolving and fast changing educational technology have posed various challenges as far as curriculum in the Higher Educational Institutions (HEIs) is concerned. The curriculum requires to be updated more often keeping in view the latest developments in the society and to address the society's needs from time to time.

The Quality Mandate notified by UGC was discussed in the Conference of Vice-Chancellors and Directors of HEIs during 26-28th July, 2018; wherein it was inter-alia resolved to revise the curriculum based on Learning Outcome Curriculum Framework (LOCF).

Learning Outcome Curriculum Framework (LOCF) aims to equip students with knowledge, skills, values, attitudes, leadership readiness/qualities and lifelong learning. The fundamental premise of LOCF is to specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study. Besides this, students will attain various 21st century skills like critical thinking, problem solving, analytic reasoning, cognitive skills, self directed learning etc.. A note on LOCF for undergraduate education is available on the UGC website www.ugc.ac.in. It can serve as guiding documents for all Universities undertaking the task of curriculum revision and adoption of outcome based approach.

To facilitate the process of curriculum based on LOCF approach, UGC had constituted subject specific Expert Committees to develop model curriculum. I feel happy to present the model curriculum to all the HEIs. Universities may revise the curriculum as per their requirement based on this suggestive model within the overall frame work of Choice Based Credit System (CBCS) and LOCF.

I express my gratitude and appreciation for the efforts put in by the Chairperson/Member/Co-opted members/experts of the committees for developing model curriculum. I also take the opportunity to thank Prof. Bhushan Patwardhan, Vice-Chairman, UGC for providing guidance to carry forward this task. My sincere acknowledgement to Prof. Rajnish Jain, Secretary, UGC for all the Administrative support. I also acknowledge the work done by Dr. (Mrs.) Renu Batra, Additional Secretary, UGC for coordinating this important exercise.

All the esteemed Vice-Chancellors are requested to take necessary steps in consultation with the Statutory Authorities of the Universities to revise and implement the curriculum based on the learning outcome based approach to further improve the quality of higher education.

New Delhi
30th July, 2019

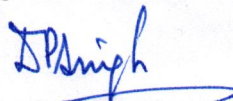

(Prof. D. P. Singh)
Chairman
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Preamble:

Statistics is used in different ways in different contexts. For a cricket fan, Statistics is the information about runs scored or wickets taken by a player. For the manager of a manufacturing unit, Statistics may be the information about the process control. For a medical researcher investigating the effects of a new drug, Statistics is the evidence of research efforts. For a college student, Statistics shows the grades or marks scored in a course. Thus, in all these illustrations, Statistics refers to quantitative data in the area under study. Statistics as a subject is an important branch of knowledge and is devoted to various techniques of collection, presentation, analysis and interpretation of data. It is a science of learning from data. The subject provides tools for making decisions when conditions of uncertainty prevail. Hence Statistical tools and techniques are used in almost all fields which are indispensable for people working in fields like agriculture, business, management, economics, finance, insurance, education, biotechnology and medical science, etc. For the last two decades, large amount of data has been handled with the help of computers and more sophisticated statistical techniques can be used in an effective manner to draw valid conclusions. Knowledge of different aspects of Statistics has become crucial in the present scenario. There is a continuous demand for statisticians in fields of education, industry, software and research. The syllabi of three-year B.Sc. (Honors) degree course in Statistics are framed in such a way that the students at the end of the course, can be thorough in statistical techniques for pursuing higher studies and simultaneously can apply statistical tools judiciously to a variety of data sets to arrive at some valid conclusions.

1. Introduction

B.Sc. (Honors.) Statistics programme consists of 148 credits spread over six semesters. Each credit has one hour of class room teaching per week. This programme emphasizes both theory and applications of statistics and is structured to provide knowledge and skills in depth necessary for the employability of students in industry, other organizations, as well as in academics.

2. Learning Outcomes Based Approach to Curriculum Planning

2.1 Nature and Extent of the B.Sc. (Honors) Programme

The B.Sc. (Honors.) Statistics Programme has some unique features such as independent projects, a number of elective courses including practical training on realistic problems, and extensive insight into statistical computations using standard statistical packages. Standard statistical packages, namely, MINITAB, MATLAB, R, MATHEMATICA, SAS, S-SPLUS, STATISTIKA, etc. are used in all practical courses and project work. The course has been designed in such a way that besides the core courses, a student can opt for outcome based elective courses from the streams such as *Financial Statistics*, *Bio-Statistics*, *Geo-Statistics*, *Actuarial Statistics*, *Computational Statistics*, *Time Series*, *Clinical Trials and Epidemiology*.

The independent project work is one of the important components of this programme which will focus on one of the streams opted by the candidate.

B.Sc. (Honors) Statistics programme is of three years duration, with semester pattern.

- During first two semesters, students will be given the basic information that includes methods of data representation and summarization. Further, they will be introduced to probability and distributions along with applications.
- During third and fourth semesters, students are expected to study statistical inference, regression analysis, numerical analysis and sampling techniques.
- During fifth and sixth semesters, some theory papers and practicals deal with theoretical as well as applied aspects of statistics. Besides, they are supposed to take up a Project Work preferably on a problem related to industries.

2.2 Aims of Bachelor's degree Programme in Statistics

- To prepare graduates who are not only statistically sound but also capable of using their appropriate statistical skills in interdisciplinary areas such as finance,

health, agriculture, government, business, industry, telecommunication, and bio-statistics. As a result, they can pursue their future career either in the core field or in the applied field of Statistics.

- To familiarize students with computational techniques and software used in the statistical arena.
- To provide a solid ground in the best practices of collating and disseminating information.
- To prepare students for undertaking further study.
- To teach students to construct practical statistical models for several processes in the real-world.

3. Graduate Attributes in Statistics

- **Disciplinary Knowledge:** The proposed curriculum is expected to provide the students a sound knowledge of Statistics covering various aspects. As a result, they will not only appear appropriate for pursuing higher studies in the subject but also develop skill to apply the statistical knowhow to a variety of real life problems.
- **Critical Thinking:** The proposed course is designed to enrich the students with ability to examine the various statistical issues in a more logical and methodical manner. It is expected that the students will strengthen themselves both computationally and analytically.
- **Problem Solving:** The students will be able to critically examine various hypotheses and research queries, and will be able to identify and consult relevant resources to find their rational answers.
- **Analytical Reasoning:** The students are expected to develop capability to identify logical flaws and loopholes in the arguments of practicing Statisticians, analyse and synthesise data from a variety of sources and accordingly draw conclusions.
- **Research Related Skills:** The students should be able to develop original thinking for formulating new problems and providing their solutions. As a result,

they will be able to develop research related skills for their own subject as well as for those who are practicing Statistics.

- **Communication Skills and Team Work:** The students are expected to develop effective and confident Communication skill after completion of the course. They will have an ability to work in a team as well as in isolation.
- **Moral and Ethical Awareness:** After completion of the course, the students are expected to develop ethical and social responsibility as well. As a result, the students will be able to identify ethical issues, avoid unethical behaviour such as fabrication, falsification or misrepresentation and misinterpretation of data.
- **Scientific Reasoning:** The students will be able to analyse, interpret and draw appropriate conclusions from both quantitative and qualitative data and critically evaluate ideas, evidence and experiences with an unbiased and consistent approach.
- **Reflective thinking:** The students should be sensitive to real experiences with respect to self, society and nation.
- **Information/Digital literacy:** The proposed course is expected to develop digital literacy among the students for using ICT in different learning situations. The students should be able to equip themselves with in depth programming and simultaneously use appropriate Statistical software for advanced Statistical computing with high level graphical interface.
- **Self-directed Learning:** The students are expected to be familiar with data collection, compilation, analysis and interpretation and writing of project reports independently.
- **Multicultural Competence:** The students are expected to be aware of values and beliefs of different cultures and have a global perspective by examining various forms of primary and secondary data resources.
- **Leadership Readiness/Qualities:** The students will be capable of mapping out the tasks of a team or an organization, formulating an inspiring vision, building a team for achieving the desired objectives, motivating and inspiring team members accordingly, and using management skills to guide people in the right direction smoothly and efficiently.
- **Lifelong Learning:** The proposed course is designed to develop independent, coherent and decisive thoughts among the students that will ultimately develop

competency in their lives. Simultaneously, they will develop entrepreneurship and intrapreneurship aptitude. This latter aspect will help them achieve risk-taking and innovative ability, an essential requirement of any large organization.

4. Qualification Descriptors

Qualification descriptors for a Bachelor's Degree with honours: The qualification descriptors for a Bachelor's degree with honours will

- demonstrate (i) a systematic, extensive, coherent knowledge of an academic field of study and its applications, links to interdisciplinary areas of study with a critical knowledge of the subject and a number of emerging issues, (ii) procedural knowledge that creates professionals in the field of Statistics including research and development, teaching, government and public services, (iii) skills in areas related to specialization and current developments in Statistics.
- demonstrate skills in collection of relevant quantitative and/or qualitative data, analysis and interpretation of data using appropriate statistical methodologies.
- use knowledge, understanding and skills for critical assessment of a wide range of ideas and complex problems and issues relating to the chosen field of study.
- communicate the results of studies undertaken in statistics in a range of different contexts using the main concepts, constructs and techniques of the subject.
- address one's learning needs relating to current and emerging areas of study, making use of research, development and professional materials as appropriate, including those related to new frontiers of knowledge.
- apply one's statistical knowledge and skills to new contexts and to identify and analyse problems and issues and seek solutions to real-life problems.
- demonstrate subject-related skills that are relevant to some of the job trades and employment opportunities.

5. Programme Learning Outcomes in B.Sc.(Hons.) Statistics

The student graduating with the Degree B.Sc. (Honors) Statistics should be able to

1. Demonstrate the ability to use skills in Statistics and its related areas of technology for formulating and tackling Statistical related problems and identifying and applying appropriate principles and methodologies to solve a wide range of problems associated with Statistics.

2. acquire
 - (i) a fundamental/systematic or coherent understanding of the academic field of Statistics, its different learning areas and applications in Medical Statistics, Actuarial Statistics, Agricultural Statistics, Geo-Statistics, Financial Statistics, Population Statistics, Financial Econometrics, Clinical Trials and Epidemiology, Queuing Theory, Stochastic Processes, etc.,
 - (ii) procedural knowledge that creates different types of professionals related to the disciplinary/subject area of Statistics, including professionals engaged in research and development, teaching and government/public service;
 - (iii) skills in areas related to one's specialization area within the disciplinary/subject area of Statistics and current and emerging developments in the field of Statistics.
3. Recognize the importance of statistical modeling simulation and computing, and the role of approximation and mathematical approaches to analyze the real world problems.
4. Plan and execute Statistical related experiments or investigations, analyze and interpret data/information collected using appropriate methods, including the use of appropriate software such as programming languages and purpose-written packages, and report accurately the findings of the experiment/investigations while relating the conclusions/findings to relevant theories of Statistics.
5. Demonstrate relevant generic skills and global competencies such as
 - (i) problem-solving skills that are required to solve different types of Statistics-related problems with well-defined solutions, and tackle open-ended problems that belong to the disciplinary-area boundaries;
 - (ii) investigative skills, including skills of independent investigation of Statistics-related issues and problems;
 - (iii) communication skills involving the ability to listen carefully, to read texts and research papers analytically and to present complex information in a concise manner to different groups/audiences of technical or popular nature;
 - (iv) analytical skills involving paying attention to detail and ability to construct logical arguments using correct technical language related to Statistics and ability to translate them with popular language when needed;
 - (v) ICT skills;
 - (vi) personal skills such as the ability to work both independently and in a group.
6. Demonstrate professional behavior such as

- (i) being objective, unbiased and truthful in all aspects of work and avoiding unethical, irrational behavior such as fabricating, falsifying or misrepresenting data or committing plagiarism;
- (ii) the ability to identify the potential ethical issues in work-related situations;
- (iii) appreciation of intellectual property, environmental and sustainability issues; and
- (iv) promoting safe learning and working environment.

5.1 Course Learning Outcomes

ST-C-1: Descriptive Statistics

Students will acquire

- (a) knowledge of Statistics and its scope and importance in various areas such as Medical, Engineering, Agricultural and Social Sciences etc.
- (b) information about various Statistical organisations in India and their functions for societal developments,
- (c) knowledge of various types of data, their organisation and evaluation of summary measures such as measures of central tendency and dispersion etc.
- (d) knowledge of other types of data reflecting quality characteristics including concepts of independence and association between two attributes,
- (e) insights into preliminary exploration of different types of data.

ST-C-2: Probability Theory and Distributions-I

Students will acquire

- (a) ability to distinguish between random and non-random experiments,
- (b) knowledge to conceptualise the probabilities of events including frequentist and axiomatic approach. Simultaneously, they will learn the notion of conditional probability including the concept of Bayes' Theorem,
- (c) knowledge related to concept of discrete random variable and its probability distribution including expectation and moments,
- (d) knowledge of important discrete distributions such as Binomial, Poisson, Geometric, Negative Binomial and Hypergeometric and their interrelations if any,
- (e) acumen to apply standard discrete **probability** distribution to different situations.

ST-C-3: Practical –I

This course is based on both ST-C-1 and ST-C-2 and will provide practical knowledge to the students on various concepts elaborated in these two courses. R programming is introduced in this practical. All standard statistical software packages, namely, MINITAB, MATLAB, R, MATHEMATICA, SAS, S-SPLUS, STATISTIKA, etc. are introduced and also used in the subsequent practical courses and projects.

ST-C-4: Statistical Methods–I

The students will acquire

- (a) knowledge about continuous random variables and their characteristics such as expectation, variance and higher order moments etc.,
- (b) concept of random sample from a distribution, sampling distribution of a statistic, standard error of important estimates such as mean and proportions,
- (c) knowledge about important inferential aspects such as point estimation, test of hypotheses and associated concepts,
- (d) knowledge about inferences from Binomial, Poisson and Normal distributions as illustrations.

ST-C-5: Probability Theory and Distributions-II

This is an advanced level course designed to provide the students

- (a) knowledge about some probability inequalities, law of large numbers, Central Limit Theorem etc.,
- (b) ability to handle transformed random variables and derive associated distributions,
- (c) knowledge of important continuous distributions such as Uniform, Normal, Exponential and Gamma and relations with some other distributions,
- (d) ability to use and interpret Normal probability and q-q plots for testing Normality of data,
- (e) knowledge about Box Mueller transformation for simulations.

ST-C-6: Practical –II

This course is based on both ST-C-4 and ST-C-5 and will provide practical knowledge to the students on various topics elaborated in these two courses so that they can apply the relevant concepts to real life problems.

ST-C-7: Statistical Methods–II

This course will acquaint the students

- (a) with various basic concepts on sampling distributions and large sample tests based on normal distribution,
- (b) with small sample tests based on chi-square, Student's and Snedecor's F distributions,
- (c) with theory of Logistic and Probit Analysis,
- (d) with knowledge of two dimensional discrete and continuous random variables, their associated distributions, characteristics, marginal and conditional distributions,
- (e) with inferential knowledge regarding the parameters of Bivariate and Multivariate Normal distributions.

ST-C-8: Statistical Inference-I

After going through this course, the students will get

- (a) a fundamental understanding of Parametric models for developing relevant inferences on associated parameters,
- (b) knowledge of point and interval estimation procedures and different methods of point estimation,
- (c) to understand the Cramer-Rao Inequality, Rao Blackwell and Lehmann Scheffe theorems and their applications in obtaining Minimum Variance Unbiased and Minimum Variance Bound estimators,
- (d) to work on several standard examples to help them understand the various inherent concepts.

ST-C-9: Sampling Techniques

The students shall get

- (a) basic knowledge of complete enumeration and sample, sampling frame, sampling distribution, sampling and non-sampling errors, principal steps in sample surveys, limitations of sampling etc.,
- (b) introduced to various statistical sampling schemes such as simple, stratified, systematic and probability proportional to size (pps) sampling,
- (c) an idea of conducting the sample surveys and selecting appropriate sampling techniques,
- (d) knowledge about comparing various sampling techniques.

ST-C-10: Practical-III

This course is based on ST-C-7, ST-C-8 and ST-C-9 and shall provide practical knowledge to the students on various topics such as small sample and large sample tests, bivariate probability distributions, estimation techniques and sampling techniques so that they can apply the relevant concepts to real life problems.

ST-C-11: Regression Analysis

The students shall

- (a) know about correlation and regression techniques, the two very powerful tools in statistics,
- (b) get an idea of Linear, Polynomial and Multiple Linear regression,
- (c) learn about regression diagnostics, multicollinearity, residual plots and estimation and tests for regression coefficients.
- (d) study concept of coefficient of determination and inference on partial and multiple correlation coefficients.

ST-C-12: Statistical Inference-II

The course will provide the students with a knowledge of

- (a) advanced level topics in statistical inference on testing of statistical hypotheses for both randomized and non-randomized tests,
- (b) using Neyman Pearson Lemma and finding Uniformly Most Powerful Test,
- (c) likelihood ratio test and its applications,
- (d) confidence interval estimation and their relationships with testing,
- (e) order statistics and their distributions,
- (f) Wald's Sequential Probability Ratio Test and concepts of ASN and OC functions,

- (g) Sequential estimation with examples based on standard probability distributions,
- (h) statistical decision problem including the concept of loss and risk functions, Bayes and Minimax Decision rules.

ST-C-13: Numerical Analysis

The students shall

- (a) demonstrate knowledge of different numerical methods, essential for providing Mathematical support to the Statisticians where intractability becomes severe,
- (b) be able to learn various difference, interpolation formulae,
- (c) be in a position to find solutions to equations using Bisection, Newton Raphson and Regula Falsi Methods,
- (d) handle numerical differentiation and integration,
- (e) be able to find solutions to difference equations of first order and linear difference equations with constant coefficients.

ST-C-14: Practical-IV

This course is based on ST-C-11, ST-C-12 and ST-C-13 and at the end of the course, students shall be able to use and apply regression techniques, obtain UMP tests and demonstrate knowledge of numerical methods.

ST-C-15: Optimization Techniques

The students shall get exposed to

- (a) graphical and simplex method of solving linear programming problem (LPP) for finding degenerate, unbounded, alternate and infeasible solutions,
- (b) post-optimality: addition of constraints, change in requirement vector, addition of new activity and change in cost vector,
- (c) use of duality to solve a LPP,
- (d) obtaining solution of a transportation problem by North West corner method, Matrix Minima method, Vogel's method,
- (e) Hungarian Method for solving assignment problems,
- (f) game theory for graphical solution of $m \times 2$ or $2 \times n$ rectangular game and mixed strategy,
- (g) networking problem using minimal spanning tree and shortest route,
- (h) optimal inventory policy for EOQ model and its variations.

- (i) solving quantity discounts model with price breaks.

ST-C-16: Statistical Quality Control and Reliability

The students will be able to

- (a) construct group control chart,
- (b) draw charts for variables and attributes,
- (c) draw CUMSUM chart,
- (d) understand single and double sampling inspection plans, OC and ASN functions,
- (e) get introduced to notion of censored data, Type I, Type II and random censoring schemes,
- (f) get idea of important lifetime distributions such as for exponential, Weibull, gamma and lognormal distributions.
- (g) compute MLEs of exponential distribution for complete and censored data,
- (h) compute MLEs of lognormal distributions,
- (i) compute MLEs of gamma and Weibull distributions using iterative procedure,
- (j) fit exponential and Weibull distributions for a given lifetime dataset,
- (k) find interval estimates for the parameters of exponential, Weibull, gamma and lognormal distributions.
- (l) Test reliability hypotheses for exponential and Weibull distributions,
- (m) evaluate system reliability for series, parallel, k out of n systems,

ST-C-17: Practical-V

This course is based on ST-C-15 and ST-C-16 and at the end of the course, students shall be able to draw different types of control charts for variables and attributes. They will also be able to understand the practical applicability of single and double sampling inspection plans.

The students will be able to get an idea of reliability and hazard function and how to discriminate among the important lifetime distributions based on hazard function.

ST-C-18: Design of Experiments

The students will be in a position to

- (a) carry out one way and two way Analysis of Variance,

- (b) understand the basic terms used in design of experiments,
- (c) use appropriate experimental designs to analyze the experimental data,
- (d) analyze 2^2 and 2^3 factorial experiments,
- (e) apply Multiple range tests, the *LSD* test or the multiple t-test, Student-Newman-Keuls test, Duncan's multiple range test, Tukey's test, Multiple F tests, Fisher's least significant difference test, Scheffe's test,
- (f) give statistical interpretation of the experimental results obtained.

ST-C-19: Non-Parametric Inference

This course will help the students to

- (a) use different nonparametric/distribution-free tests when data don't meet the assumptions of parametric test,
- (b) understand importance of different non-parametric test procedures, their applications and interpretation,
- (c) analyse categorical data using logistic regression models.

ST-C-20: Practical – VI

This course is based on ST-C-18 and ST-C-19 and at the end of the course, students shall be able to analyse data using various non-parametric tests. Also, the students will be in a position to visualize the scope of experimental designs in getting valid and efficient results. As a result, they will decide to select an appropriate experimental design and analyse the same to interpret the results so obtained.

Discipline Specific Elective (DSE) Courses

ST-DSE-1: Time Series Analysis

This course is meant to acquaint the students with some important but useful concepts on topics in time series analysis so that the students can get an important background material for taking up an advanced course in financial econometrics and data analysis. After completion of this course, the students will know about

- (a) time series data, its applications to various fields and components of time series,
- (b) fitting and plotting of various growth curves such as modified exponential, Gompertz and logistic curve,
- (c) fitting of trend by Moving Average method,
- (d) measurement of Seasonal Indices by Ratio-to-Trend , Ratio-to-Moving Average and Link Relative methods,
- (e) calculation of variance of random component by variate component method,
- (f) forecasting by exponential smoothing and short term forecasting methods such as Box Jenkins Method and Bayesian forecasting,
- (g) weak stationarity, autocorrelation and correlogram,
- (h) applications to real data by means of laboratory assignments.

ST-DSE-2: Actuarial Statistics

This course is framed to equip the students with concepts of actuarial science and different premium models. After opting for this course, the students will be equipped with knowledge about

- (a) modelling of individual and aggregate losses,
- (b) fitting of distributions to claims data, deductibles and retention limits, proportional and excess-of-loss reinsurance,
- (c) Risk models: models for individual claims and their sums,
- (d) finding distribution of aggregate claims, compound distributions and their applications,
- (e) applications of credibility theory,
- (f) finding of survival function, curate future lifetime, force of mortality,
- (g) handling problems on joint life and last survivor status and multiple decrement model,
- (h) mean and variance of various continuous and discrete payments for assurance and annuity contracts,

- (i) calculation of various payments from life tables using principle of equivalence, net premiums, prospective and retrospective provisions/reserves,
- (j) real illustrations for the concepts mentioned above through laboratory assignments.

ST-DSE-3: Survival Analysis

The course gives the application of statistics in handling survival data. The students will know about concepts of

- (a) Type-I (time), Type-II (order) and random censoring,
- (b) Survival Function, Failure rate, mean residual life, Total time on Test,
- (c) applications of exponential, gamma, Weibull distributions, lognormal, Pareto, linear failure rate distributions to lifetime data,
- (d) ageing properties of IFR, IFRA, DMRL, NBU, NBUE and HNBUE and Dual classes.
- (e) Actuarial and Kaplan –Meier estimator of survival function,
- (f) Cox’s proportional hazards and competing risk models,
- (g) tests for exponentiality,
- (h) Real lifetime data implementation of various concepts as outlined above through practical assignments.

ST-DSE-4: Applied Statistics

After going through this course, the students will have an idea of

- (a) income distributions and their fitting in real life situations,
- (b) commonly used measures of demography pertaining to its three basic aspects, viz. the fertility, mortality and migration,
- (c) various data collection methods enabling them to have a better insight in policy making, planning and systematic implementation,
- (d) Construction and implication of life tables,
- (e) Population growth curves, population estimates and projections,
- (f) Real data implementation of various demographic concepts as outlined above through practical assignments.

ST-DSE-5: Financial Statistics

The course is designed to provide the students with

- (a) various Mathematical and Statistical concepts applicable in the area of Financial Statistics,
- (b) some elementary concepts in Financial Statistics leading to generalized cash flow models,
- (c) Some advanced level concepts such as compound interest function including level and non-level annuities, continuous payment cash flows etc.,
- (d) Investment and risk characteristics involved with different types of assets,
- (e) Some simple stochastic models for investment returns etc.,
- (f) Sufficient practical training on relevant concepts by means of laboratory assignments.

ST-DSE-6: Clinical Trials and Epidemiology

The course is of applied nature and will provide the students about

- (a) the basic idea of various terminologies in epidemiology, clinical trial experiments involving different phases etc.,
- (b) the ethics, principles and conduct of clinical trial experiments with an overall view of Phase I-IV trials,
- (c) various data management and data collection systems for a good clinical trial practice,
- (d) population pharmacokinetics and pharmacodynamics models applicable in clinical trials,
- (e) various clinical trial designs commonly employed in practice,
- (f) design and monitoring of Phase III trials with various stopping rule, the inferential aspects including classical methods of interval estimation and hypotheses testing etc.,
- (g) design and analysis of epidemiological studies including case-control and cohort study designs,
- (h) sufficient practical knowledge by means of laboratory assignments on different types of real life data sets.

ST-DSE-7: Geo-Statistics

This course will provide the students an idea of

- (a) basic geostatistical concepts including the topics on spatial data analysis,
- (b) drawing important inferences on geostatistical and spatial data problems,

- (c) various graphical techniques relevant to geostatistical and spatial data analysis
- (d) variogram models and their analysis, maximum likelihood and Bayesian method on such aspects
- (e) krigging and its importance in geostatistical and spatial data problems
- (f) real data applications through laboratory assignments on the relevant inferential aspects including estimation and testing.

ST-DSE-8: Econometrics

The course on econometrics will primarily focus on the use of statistical modelling and the relevant analyses to economic data problems. The students will get a thorough idea of

- (a) various important econometric models and relevant model building concepts in econometrics
- (b) general linear models and estimation of inherent model parameters
- (c) multicollinearity, its detection and consequences and related inferential aspects
- (d) some advanced concepts of generalised least squares estimation, autocorrelation, its consequences, detection and strategy for reducing autocorrelation,
- (e) heteroscedasticity and its inherent concepts including its consequences,
- (f) some inferential aspects on heteroscedasticity,
- (g) practical aspects and real data illustration of the related problem

ST-DSE-9: Stochastic Processes and Queuing Theory

The students will get acquainted with some important and useful concepts on

- (a) probability distributions, generating functions including bivariate generating functions etc.,
- (b) Markov chains including the notion of transition probability matrix
- (c) various other stochastic processes such as Poisson process, birth and death processes, queuing process and Gambler ruin problems,
- (d) application of these processes in real life problems,
- (e) practical aspects relevant to above problems based on the considered topics.

ST-DSE-10: Project

Students will opt for a compulsory industrial Project in Semester VI. At the end of this project, students will be in a position to

- (a) analyze and interpret and take appropriate decisions in solving real life problems using statistical tools.
- (b) use different Statistical packages for graphical interface, data analysis and interpretation,
- (c) write a systematic Statistical project report.

Generic Electives/Interdisciplinary Courses

ST-GE-1: Introduction to Statistics

This course is designed for students other than statistics discipline and can be opted as choice based credit system (CBCS). This course will make the students conversant with

- (a) various techniques used in summarization, presentation and analysis of different types of Statistical data,
- (b) various summary measures of central tendency, dispersion, moments, skewness and kurtosis.
- (c) simple and rank correlation, Partial and Multiple correlation coefficients.
- (d) fitting of linear and quadratic regressions using principle of least squares.
- (e) measures of association for 2×2 and $r \times s$ contingency tables.
- (f) have knowledge on theoretical as well as practical approach.

ST-GE-2: Introduction to Probability Theory

This course is designed for students other than statistics discipline and can be opted as choice based credit system (CBCS). This course will lay the foundation to probability theory and

Statistical modeling of outcomes of real life random experiments through various Statistical distributions. The students will get to know about

- (a) writing of sample space, events and algebra of events and finding Probability of events,
- (b) conditional Probability and applications of Theorem of total probability and Bayes' theorem,
- (c) discrete and continuous Random Variables, Probability mass function (p.m.f.) and Probability density function (p.d.f.), Cumulative distribution function (c.d.f.)
- (d) Expectation, variance, moments and moment generating function.

- (e) problem solving pertaining to binomial, Poisson, geometric, negative binomial, hyper geometric, uniform, normal, exponential, beta, gamma distributions.
- (f) fitting of Binomial, Poisson and Normal distributions
- (g) Chebyshev's inequality, Convergence in probability, Weak law of large numbers, Convergence in distribution, De-Moivre Laplace and Lindeberg-Levy Central Limit Theorems (C.L.T.),
- (h) various aspects as outlined above through practical assignments.

ST-GE-3: Introduction to Statistical Inference

This course is designed for students other than statistics discipline and can be opted as choice based credit system (CBCS). The students will get an exposure to

- (a) techniques of estimation and testing of hypotheses for mean, variance, proportions, correlation coefficient, association and goodness of fit,
- (b) confidence intervals for the parameters of a normal distribution (one and two-sample problems),
- (c) Test of significance for correlation coefficient, Fisher's z -transformation,
- (d) Tests of proportions, tests of association and goodness-of-fit using Chi-square test, Yates' correction,
- (e) analysis of variance technique for one and two way classifications,
- (f) analysis of commonly used experimental designs such as CRD, RCBD etc.,
- (g) non-parametric tests such as Sign test for median and symmetry, Wilcoxon two-sample test,
- (h) practical applications through laboratory assignments.

ST-GE-4: Introduction to Applied Statistics

The course will expose the students to

- (a) time series, index numbers, quality control and demographic methods,
- (b) different methods of measurements in time series
- (c) computation of different types of index numbers, consumer price index number,
- (d) quality control charts for variables and attributes helpful in industry for maintaining quality,
- (e) measures of fertility and mortality useful for helping the govt. to make decisions,
- (f) practical applications of the various concepts outlined above.

ST-GE-5: Introduction to Operations Research

The students shall get exposed to

- (a) graphical and simplex method of solving linear programming problem (LPP) for finding degenerate, unbounded, alternate and infeasible solutions,
- (b) use of duality to solve a LPP,
- (c) obtaining solution of a transportation problem by North West corner method, Matrix Minima method, Vogel's method,
- (d) Hungarian Method for solving assignment problems,
- (e) game theory, minimax-maximin rules, graphical solution of $m \times 2$ or $2 \times n$ rectangular game and mixed strategy,
- (f) networking problem using shortest route.

Skill Enhancement Courses (SEC)

ST-SEC-1: Computational Techniques and R Programming

The students will get acquainted with

- (a) various basic concepts related to computer architecture and its organization, various peripheral devices,
- (b) languages: machine language, assembly language and high level languages,
- (c) ideas on operating systems, linker, loader and compiler etc.,
- (d) R programming with some basic notions for developing their own simple programs and visualizing graphics in R.

ST-SEC-2: Computational Statistics and Database Management System

The students shall be exposed to

- (a) various computational algorithms relevant to statisticians as support system,
- (b) codes preferably using R language,
- (c) Linear congruential and mid-square methods for uniform generator,
- (d) Inverse transform method for simulating various probability distributions and stochastic models,
- (e) data base management system with special emphasis on significance of topic to the statisticians,
- (f) Entity relationship, Relational, Hierarchical and Network Models,
- (g) practical assignments on above mentioned topics.

ST-SEC-3: Statistical Techniques for Research Methods

Statistical Techniques provide scientific approaches to develop the domain of human knowledge largely through empirical studies. The course will enable the students to

- (a) understand basic concepts and aspects related to research, data collection, analyses and interpretation,
- (b) Prepare and finalize research report on some real life situations.

Tables of Course Learning Outcomes

Table 1						
B.Sc. Statistics (Honors)- First year-Core Courses						
Programme Outcomes	ST-C-1	ST-C-2	ST-C-3	ST-C-4	ST-C-5	ST-C-6
Outcome 1	X	X	X	X	X	X
Outcome 2						
Outcome 3						
Outcome 4			X			X
Outcome 5			X			X
Outcome 6						

Table 2								
B.Sc. Statistics (Honors)- Second year-Core Courses								
Programme Outcomes	ST-C-7	ST-C-8	ST-C-9	ST-C-10	ST-C-11	ST-C-12	ST-C-13	ST-C-14
Outcome 1	X	X	X	X	X	X		X
Outcome 2					X			
Outcome 3							X	X
Outcome 4				X				X
Outcome 5				X				X
Outcome 6			X					

Table 3**B.Sc. Statistics (Honors)- Third year-Core Courses**

Programme Outcomes	ST-C-15	ST-C-16	ST-C-17	ST-C-18	ST-C-19	ST-C-20
Outcome 1		X	X	X	X	X
Outcome 2	X	X		X		
Outcome 3	X		X			
Outcome 4			X			X
Outcome 5			X			X
Outcome 6				X		

Table 4**B.Sc. Statistics (Honors): DSE Courses**

Programme Outcomes	ST-DSE-1	ST-DSE-2	ST-DSE-3	ST-DSE-4	ST-DSE-5	ST-DSE-6	ST-DSE-7	ST-DSE-8	ST-DSE-9	ST-DSE-10
Outcome 1				X					X	X
Outcome 2	X	X	X	X	X	X	X	X	X	X
Outcome 3	X		X		X	X			X	X
Outcome 4	X	X	X	X	X	X	X	X	X	X
Outcome 5	X	X	X	X	X	X	X	X	X	X
Outcome 6						X				X

Table 5**B.Sc. Statistics (Honors): GE & SEC Courses**

Programme Outcomes	ST-GE-1	ST-GE-2	ST-GE-3	ST-GE-4	ST-GE-5	ST-SEC-1	ST-SEC-2	ST-SEC-3
Outcome 1	X	X	X	X				X
Outcome 2				X	X			X
Outcome 3						X	X	
Outcome 4	X	X	X	X	X			
Outcome 5	X	X	X	X	X	X	X	
Outcome 6								X

6. Structure of B.Sc. (Hons) (Statistics)

Course	Credits
I. <u>Core Course</u>	
(14 Theory papers of 4 credits each)	14X4=56
(4 Practicals of 4 credits each)	4X4=16
(2 Practicals of 6 credits each)	2X6=12

Total	84 credits
II. <u>Elective Course</u>	
A. Discipline Specific Elective (DSE)	
(4 Theory papers of 4 credits each)	4X4=16
(4 Practicals of 2 credits each)	4X2=8
B. Generic Elective/Interdisciplinary (GE)	
(4 Theory papers of 4 credits each)	4X4=16
(4 Practicals of 2 credits each)	4X2=8

Total	48 credits
<ul style="list-style-type: none"> • Optional Dissertation or project work in place of one Discipline Specific Elective paper (6 credits) in 6th semester 	
III. Ability Enhancement Courses	
1. Ability Enhancement Compulsory Courses (AECC)	
(2 Theory papers of 4 credits each)	2X4=8
2. Skill Enhancement Courses (SEC)	
(2 Theory papers of 3 credits each)	2X3=6
(2 Practicals of 1 credit each)	2X1=2

Total	16 credits
Total Credits	148

- University/Institute should evolve a system/policy about ECA/General Interest/Sports/NCC/NSS/related courses on its own.

Sem No.	Core course (20)	Ability Enhancement Compulsory Course (AECC) (2)	Skill Enhancement Course (SEC) (2)	Discipline Specific Elective (DSE) (4)	Generic Elective (GE) (4)
I	1. Descriptive Statistics ----- 2. Probability Theory and Distributions-I ----- 3. Practical-I	(English/Hindi/MIL Communication)/ Environmental Science			Any one from the list of GE
II	1.Statistical Methods-I ----- 2. Probability Theory and Distributions-II ----- 3.Practical-II	(English/Hindi/MIL Communication)/ Environmental Science			Any one from the list of GE
III	1.Statistical Methods-II ----- 2.Statistical Inference-I ----- 3.Sampling Techniques ----- 4.Practical-III		Any one from the list of SEC		Any one from the list of GE
IV	1.Regression Analysis ----- 2.Statistical Inference-II ----- 3.Numerical Analysis ----- 4.Practical-IV		Any one from the list of SEC		Any one from the list of GE
V	1.Optimization Techniques ----- 2.Statistical Quality Control and Reliability ----- 3.Practical-V			Any two from the list of DSE	
VI	1.Design of Experiments ----- 2.Nonparametric Inference ----- 3.Practical-VI			Any two from the list of DSE	

Course Code	Course Name	Course Type	Credits
SEMESTER I			
ST-C-1	Descriptive Statistics	Core	04
ST-C-2	Probability Theory and Distributions-I	Core	04
ST-C-3	Practical –I	Core	04
Generic Elective	Any one from the list of Generic Elective/Interdisciplinary courses from other Department	Generic Elective	06 (04(Theory)+02(Practical))
AECC-1	(English/Hindi/MIL communication)/ Environmental Science	Ability Enhancement	04
SEMESTER II			
ST-C-4	Statistical Methods-I	Core	04
ST-C-5	Probability Theory and Distributions-II	Core	04
ST-C-6	Practical –II	Core	04
Generic Elective	Any one from the list of Generic Elective/Interdisciplinary courses from other Department	Generic Elective	06 (04(Theory)+02(Practical))
AECC-2	(English/Hindi/MIL communication)/ Environmental Science	Ability Enhancement	04
SEMESTER III			
ST-C-7	Statistical Methods-II	Core	04
ST-C-8	Statistical Inference-I	Core	04
ST-C-9	Sampling Techniques	Core	04
ST-C-10	Practical –III	Core	06

Skill Enhancement	Any one from the list of Skill Enhancement courses from other Department	Skill Enhancement	04 (03(Theory)+01(Practical))
Generic Elective	Any one from the list of Generic Elective/Interdisciplinary courses from other Department	Generic Elective	06 (04(Theory)+02(Practical))
SEMESTER IV			
ST-C-11	Regression Analysis	Core	04
ST-C-12	Statistical Inference-II	Core	04
ST-C-13	Numerical Analysis	Core	04
ST-C-14	Practical –IV	Core	06
Skill Enhancement	Any one from the list of Skill Enhancement courses from other Department	Skill Enhancement	04 (03(Theory)+01(Practical))
Generic Elective	Any one from the list of Generic Elective/Interdisciplinary courses from other Department	Generic Elective	06 (04(Theory)+02(Practical))
SEMESTER V			
ST-C-15	Optimization Techniques	Core	04
ST-C-16	Statistical Quality Control and Reliability	Core	04
ST-C-17	Practical –V	Core	04
Discipline Specific Elective	Any one from the list of Discipline Specific Courses	Discipline Specific Elective	06 (04(Theory)+02(Practical))
Discipline Specific Elective	Any one from the list of Discipline Specific Courses	Discipline Specific Elective	06 (04(Theory)+02(Practical))
SEMESTER VI			
ST-C-18	Design of Experiments		04
ST-C-19	Non-Parametric Inference		04

ST-C-20	Practical –VI		04
Discipline	Any one from the list of	Discipline	06 (04(Theory)+
Specific Elective	Discipline Specific Courses	Specific Elective	02(Practical))
ST-DSE-10	Project		06

Discipline Specific Elective Papers (6 credits each) (Any 4 papers to be selected)

ST-DSE-1: Time Series Analysis

ST-DSE-2: Actuarial Statistics

ST-DSE-3: Survival Analysis

ST-DSE-4: Applied Statistics

ST-DSE-5: Financial Statistics

ST-DSE-6: Clinical Trials and Epidemiology

ST-DSE-7: Geostatistics

ST-DSE-8: Econometrics

ST-DSE-9: Stochastic Processes and Queuing Theory

ST-DSE-10: Project (Sixth semester) (Compulsory)

Generic Electives/Interdisciplinary Papers (6 credits each) (Statistics students will opt 4 GE papers offered by other Departments/Disciplines. Students from other Departments/disciplines shall opt for any 4 papers from the following 5 GE courses.)

ST-GE-1: Introduction to Statistics

ST-GE-2: Introduction to Probability Theory

ST-GE-3: Introduction to Statistical Inference

ST-GE-4: Introduction to Applied Statistics

ST-GE-5: Introduction to Operations Research

Skill Enhancement Courses (4 credits each) (Any 2 papers to be selected)

ST-SEC-1: Computational Techniques and R Programming

ST-SEC-2: Computational Statistics and Database Management System

ST-SEC-3: Statistical Techniques for Research Methodology

Important Remarks:

1. An internship of minimum 30 days during summer vacations in between 4th and 5th semester is optional to students which will enable them to enhance knowledge of statistics and its actual applications in real life problems.
2. Students are advised to take Mathematics GE papers offered by Mathematics Department which will give sound foundation for their higher studies.
3. University has complete freedom to suggest their own DSE courses depending upon the availability of teaching staff, their expertise, specialization, requirements, scope and need.

Syllabi of Core**Courses ST-C-1: Descriptive Statistics****Learning outcomes:**

Students will acquire

- (a) knowledge of Statistics and its scope and importance in various areas such as Medical, Engineering, Agricultural and Social Sciences etc.
- (b) information about various Statistical organisations in India and their functions for societal developments,
- (c) knowledge of various types of data, their organisation and evaluation of summary measures such as measures of central tendency and dispersion etc.
- (d) knowledge of other types of data reflecting quality characteristics including concepts of independence and association between two attributes,
- (e) insights into preliminary exploration of different types of data.

Contents:**Unit I**

Introduction to Statistics, Meaning of Statistics as a Science, Importance of Statistics. Scope of Statistics in Industry, Biological sciences, Medical sciences, Economics, Social Sciences, Management sciences, Agriculture, Insurance, Information technology, Education and Psychology. Statistical organizations in India and their functions: CSO, ISI, NSS, IIPS (Devnar, Mumbai), Bureau of Economics and statistics.

Unit II

Population and Sample. Variables: Interval scale, ratio scale, discrete and continuous variables, difference between linear scale and circular scale.

Primary and secondary data, Cross-sectional data, time series data, directional data.

Notion of a statistical population: Finite population, infinite population, homogeneous population and heterogeneous population. Notion of a sample and a random sample.

Summary Statistics. Review / Revision of Presentation of Data.

Unit III

Classification: Raw data and its classification, ungrouped frequency distribution, Sturges' rule, grouped frequency distribution, cumulative frequency distribution, inclusive and exclusive methods of classification, Open end classes, and relative frequency distribution.

Measures of Central Tendency. Partition Values: Quartiles, Deciles and Percentiles (for ungrouped and grouped data), Box Plot. Measures of Dispersion, Moments, Skewness and Kurtosis.

Unit IV

Theory of Attributes: Nominal scale, ordinal scale, classification, notion of manifold classification, dichotomy, class- frequency, order of class, positive class-frequency, negative class frequency, quanta class frequencies, ultimate class frequency, relationship among different class frequencies (up to three attributes), dot operator to find the relation between frequencies, fundamental set of class frequencies.

Consistency of data up to 2 attributes. Concepts of independence and association of two attributes. Yule's coefficient of association (Q), $-1 \leq Q \leq 1$, interpretation. Examples and Problems.

References:

1. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2013). Fundamental of Statistics, Vol I , World Press, Kolkata.

2. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2011). Fundamental of Statistics, Vol II, World Press, Kolkata.
3. Hanagal, D. D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.
4. Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
5. Mood, A.M. Graybill, F.A. and Boes, D.C. (2011). Introduction to the Theory of Statistics, 3rd Edn., Tata McGraw-Hill Pub. Co. Ltd.

ST-C-2: Probability Theory and Distributions-I

Learning Outcomes:

Students will acquire

- (a) ability to distinguish between random and non-random experiments,
- (b) knowledge to conceptualise the probabilities of events including frequentist and axiomatic approach. Simultaneously, they will learn the notion of conditional probability including the concept of Bayes' Theorem,
- (c) knowledge related to concept of discrete random variable and its probability distribution including expectation and moments,
- (d) knowledge of important discrete distributions such as Binomial, Poisson, Geometric, Negative Binomial and Hyper-geometric and their interrelations if any,
- (e) acumen to apply standard discrete probability distribution to different situations.

Contents:

Unit I

Review of probability, conditional probability, independence. Experiments/Models, Ideas of deterministic and non-deterministic models. Random Experiment, concept of statistical regularity.

Definitions of - (i) Sample space, (ii) Discrete sample space: finite and countably infinite, (iii) Event, (iv) Elementary event, (v) Complement of an event. (vi) Certain event (vii) Impossible event.

Unit II

Concept of occurrence of an event. Algebra of events and its representation in set theory notation. Occurrence of following events. (i) at least one of the given events, (ii) none of the given events, (iii) all of the given events, (iv) mutually exclusive events, (v) mutually exhaustive events, (vi) exactly one event out of the given events.

Classical definition of probability and its limitations. Probability model, probability of an event, equiprobable and non-equiprobable sample space, Axiomatic definition of probability.

Definition of conditional probability of an event. Definition of independence of two events.

Pairwise independence and mutual independence for three events. Multiplication theorem and its generalization.

Unit III

Bayes' Theorem: Partition of the sample space, Proof of Bayes' theorem. Applications of Bayes' theorem in real life.

Concept and definition of a discrete random variable. Probability mass function (p.m.f.) and cumulative distribution function (c.d.f.) $F(\cdot)$ of discrete random variable, properties of c.d.f. Mode and median of a univariate discrete probability distribution.

Mathematical Expectation (Univariate Random Variable), expectation of a function of a random variable, moment generating function (m.g.f.) and cumulant generating function (c.g.f.), Properties of m.g.f. and c.g.f.

Unit IV

Variance, standard deviation (s.d.) and Coefficient of variation (c.v.) of univariate probability distribution, effect of change of origin and scale on mean, variance and s.d., raw, central and factorial raw moments of univariate probability distributions and their interrelations (without proof). Coefficients of skewness and kurtosis based on moments.

Some Standard Discrete Probability Distributions. Degenerate distribution (one-point distribution), mean and variance.

Evaluation of p.m.f., c.d.f., mean, variance, m.g.f. and c.g.f. of the following distributions:

Uniform discrete distribution, Bernoulli distribution, Binomial distribution, Poisson distribution, Geometric distribution, Negative binomial distribution, Hypergeometric distribution. Approximation of binomial to Poisson.

References:

1. Dudewicz, E.J. and Mishra, S.N. (2008). Modern Mathematics Statistics, Wiley.
2. Hanagal, D. D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.
3. Johnson, S. and Kotz, S. (1972). Distribution in Statistics Vol. I-II & III, Houghton and Mifflin.
4. Lipschutz, S., Lipson, M. L. and Jain, K. (2010). Schaum's Outline of Probability. 2nd Edition. McGraw Hill Education Pvt. Ltd, New Delhi.
5. Pitman, J. (1993). Probability. Narosa Publishing House.
6. Rao, C.R. (2009). Linear Statistical Inference and its Applications, 2nd Edition, Wiley Eastern.
7. Rohatgi, V.K. and Saleh, A.E. (2008). An introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.

ST-C-3: Practical-I**Learning Outcomes:**

This course is based on both ST-C-1 and ST-C-2 and will provide practical knowledge to the students on various concepts elaborated in these two courses. The learning outcomes of this course are similar to those of ST-C-1 and ST-C-2. R programming is introduced in this practical. All standard statistical software packages, namely, MINITAB, MATLAB, R, MATHEMATICA, SAS, S-PLUS, STATISTIKA, etc. are introduced and also used in the subsequent practical courses and projects.

Contents:

The following is the list of experiments to be done during this course.

1. R programming, importing and exporting data, R functions, loops, conditional statements, R graphics.

2. Diagrammatic representation of statistical data problems based on simple and subdivided bar diagrams, pie diagram.
3. Graphical representation of statistical data.
4. Computation of measures of central tendency and dispersion. Use of an appropriate measure and interpretation of results.
5. Moments, Measures of skewness and kurtosis, Box plot.
6. Fitting of binomial distribution and computation of expected frequencies, mean variance, m.g.f.
7. Fitting of Poisson distribution and computation of expected frequencies, mean variance, m.g.f.
8. Fitting of geometric distribution and computation of expected frequencies, mean variance, m.g.f.
9. Fitting of hypergeometric distribution and computation of expected frequencies, mean variance, m.g.f.
10. Fitting of negative binomial distribution and computation of expected frequencies, mean variance, m.g.f.
11. Fitting of hypergeometric and negative binomial distributions and computation of expected frequencies.
12. Mutually exclusive events, conditional probability of an event, independence of two events, Pairwise independence and mutual independence for three events.
13. Bernoulli Distribution: p.m.f., mean, variance, m.g.f.
14. Binomial Distribution: p.m.f., mean, variance, m.g.f.
15. Computation of inverse probability using Baye's theorem.
16. Theory of Attributes: Nominal scale, ordinal scale, classification.
17. Consistency of data up to 2 attributes. Concepts of independence and association of two attributes.
18. Yule's coefficient of association (Q), interpretation. Examples and Problems.

References:

As specified in ST-C-1 and ST-C-2.

ST-C-4: Statistical Methods-I

Learning outcomes:

The students will acquire

- (a) knowledge about continuous random variables and their characteristics such as expectation, variance and higher order moments etc.,
- (b) concept of random sample from a distribution, sampling distribution of a statistic, standard error of important estimates such as mean and proportions,
- (c) knowledge about important inferential aspects such as point estimation, test of hypotheses and associated concepts,
- (d) knowledge about inferences from Binomial, Poisson and Normal distributions as illustrations.

Contents:

Unit I

Continuous sample space: Definition, illustrations. Continuous random variable: Definition, probability density function (p.d.f.), cumulative distribution function (c.d.f.) properties of c.d.f. (without proof), probabilities of events related to r. v.

Expectation of continuous random variable (r.v.), expectation of function of r.v., variance, moments, skewness, kurtosis.

Unit II

Concept of random sample from a distribution, statistic and its sampling distribution, standard error of an estimate, standard errors of sample mean and proportion, sampling distribution of sum of Binomial, Poisson random variables and mean of normal distribution, requirement of a good estimator with examples.

Unit III

Formulation of inference problems with concrete illustrations. Point estimation: Different methods and criteria for good estimates. Data analytic illustrations.

Unit IV

Tests of hypotheses: Simple, composite null and alternative hypotheses, critical region, types of error, level of significance, p-values, size and power of a test.

Tests for parameters when sampling is done from one and two normal distributions. Tests for parameters of binomial and Poisson distributions.

References:

1. Freedman, D., Pisani, R. and Purves, R. (2014). Statistics. 4th Edition. Norton & Comp.
2. Hanagal, D. D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.
3. Kendall, M.G. and Stuart, A. (1979). The Advanced Theory of Statistics, Vol. 2. Inference and Relationship. 4th Edition. Charles Griffin & Comp.
4. Kendall, M.G., Stuart, A. and Ord, J.K. (1994). The Advanced Theory of Statistics, Vol. 1. Distribution Theory. 6th Edition. Halsted Press (Wiley Inc.).
5. Kenney, J.F. and Keeping, E.S. (1947). Mathematics of Statistics. Part I. 2nd Edition. Chapman & Hall.
6. Kenney, J.F. and Keeping, E.S. (1951). Mathematics of Statistics. Part II. 2nd Edition. Chapman & Hall.
7. Tanner, M. (1990). An Investigation for a Course in Statistics. McMillan, New York.
8. Tanur, J.M. (1989) Statistics. A Guide to the Unknown. 3rd Edition, Duxbury Press.
9. Yule, G.U. and Kendall, M.G. (1973). An Introduction to the Theory of Statistics. 14th Edition. Charles Griffin & Comp.

ST-C-5: Probability Theory and Distributions-II

Learning Outcomes:

This is an advanced level course designed to provide the students

- (a) knowledge about some probability inequalities, law of large numbers, Central Limit Theorem etc.,
- (b) ability to handle transformed random variables and derive associated distributions,
- (c) knowledge of important continuous distributions such as Uniform, Normal, Exponential and Gamma and relations with some other distributions,

- (d) ability to use and interpret Normal probability and q-q plots for testing Normality of data,
- (e) knowledge about Box Mueller transformation for simulations.

Contents:

Unit I

Chebyshev's inequality, Convergence in probability, Weak law of large numbers, Convergence in distribution, De-Moivre Laplace and Lindeberg-Levy Central Limit Theorems (C.L.T.). Moment generating function (M.G.F.): Definition and properties, Cumulant generating function, definition, properties. Probability distribution of transformation of r. v.

Unit II

Standard univariate continuous distributions: Uniform or Rectangular Distribution: Probability density function (p. d. f.), c. d. f., sketch of p. d. f. and c. d. f., mean, variance, symmetry. Distribution of $Y = F(X)$, where $F(X)$ is the c. d. f. of continuous r. v. X .

Unit III

Normal Distribution: Probability density function (p. d. f.), p. d. f. Curve, identification of scale and location parameters, mean, variance, M.G.F., C.G.F., central moments, cumulants, median, mode, quartiles, mean deviation, additive property, computations of normal probabilities using normal probability integral tables, probability distribution of standard normal variable (S.N.V.), probability distribution of the mean of n i.i.d. r.v.s., normal probability plot, q-q plot to test normality.

Unit IV

Simulation using Box-Muller transformation. Normal approximation to i) binomial distribution ii) Poisson distribution. Exponential Distribution: Probability density function (p. d. f.), mean, variance, M. G. F., C. G. F., c. d. f., graph of c. d. f., lack of memory property, median, quartiles. Gamma Distribution: Probability density function (p. d. f.), special cases, M. G. F., C. G. F., moment, cumulants, mode, Relation between distribution function of Poisson and Gamma variates.

References:

1. Dudewicz, E.J. and Mishra, S.N. (1988). Modern Mathematics Statistics, Wiley.
2. Johnson, S. and Kotz, S. (1972). Distribution in Statistics Vol. I-II & III, Houghton and Mifflin.

3. Lipschutz, S., Lipson, M. L. and Jain, K. (2010). Schaum's Outline of Probability. 2nd Edition. McGraw Hill Education Pvt. Ltd, New Delhi.
4. Pitman, J. (1993). Probability. Narosa Publishing House.
5. Rao, C.R. (2009). Linear Statistical Inference and its Applications, 2nd Edition, Wiley Eastern.

6. Rohatgi, V.K. and Saleh, A.E. (2008). An introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.

ST-C-6: Practical II

Learning Outcomes:

This course is based on both ST-C-4 and ST-C-5 and will provide practical knowledge to the students on various topics elaborated in these two courses so that they can apply the relevant concepts to real life problems. Learning outcomes of this course are similar to those of ST-C-4 and ST-C-5.

Contents

1. Finding Point estimators.
2. Testing for parameters when sampling is done from one and two normal distributions.
3. Testing for parameters of binomial and Poisson distributions.
4. Testing for parameters of geometric and negative binomial distributions.
5. Finding probabilities of events and cumulative distribution function (c.d.f.),
6. Expectation, expectation of function of r.v. $E[g(X)]$, variance, moments, skewness, kurtosis.
7. Moment generating function (M.G.F.), Cumulant generating function (C.G.F.).
8. Finding Probability distributions of transformation of r.v.
9. Drawing random sample from uniform, normal, exponential, and gamma distributions.
10. Point estimates of the parameters of uniform, normal, exponential and gamma distributions.
11. Testing for parameters of uniform, normal, exponential and gamma distributions.
12. Applications of Uniform, Normal, Exponential, Gamma Distributions.
13. Normal probability plot, q-q plot to test normality.
14. Simulation using Box-Muller transformation.
15. Applications of central limit theorem for i.i.d. r.v.s. with finite variance.
16. Power of the test statistics.

References:

As specified in ST-C-4 and ST-C-5.

ST-C-7: Statistical Methods-II**Learning Outcomes:**

This course will acquaint the students with

- (a) various basic concepts on sampling distributions and large sample tests based on normal distribution,
- (b) small sample tests based on chi-square, Student's and Snedecor's F distributions,
- (c) theory of Logistic and Probit Analysis,
- (d) knowledge of two dimensional discrete and continuous random variables, their associated distributions, characteristics, marginal and conditional distributions,
- (e) inferential knowledge regarding the parameters of Bivariate and Multivariate Normal distributions,

Contents:**Unit I**

Sampling distributions of sample proportion, sample mean and sample variance. Central and non-central Chi-square, t and F distributions. Testing of equality of two means and two variances of two normal distributions, testing for the significance of sample correlation coefficient.

Use of central limit theorem for testing a single mean, single proportion, equality of two means and two proportions, Fisher's Z transformation and its uses, Pearson's chi-square test for goodness of fit, test of independence of two attributes.

Unit II

Logistic and probit analysis with data analytic illustrations.

Distribution theory for linear and quadratic forms. Large-sample tests and confidence intervals. Variance stabilizing transformations. Chi-square tests for independence and homogeneity. Data analytic illustrations.

Unit III

Definition of two-dimensional discrete and continuous random variable, joint p.m.f. and p.d.f., distribution function and properties, concept of identically distributed r.v.s. Computation of probabilities of events in bivariate probability distribution. Concepts of marginal and conditional probability distributions. Definition of raw and central joint moments, joint m.g.f, joint c.g.f.

Unit IV

Theorems on expectation. Conditional expectation and conditional variance, Variance of linear combination of variables. Definition of covariance, coefficient of correlation, independence and uncorrelatedness of two variables. Independence of two random variables, additive property of discrete and continuous distributions. Conditional distribution of X given (X+Y) of Binomial distribution. Examples and Problems.

Statistical inference for parameters in bivariate normal distribution, Statement of central limit theorem for i. i. d. r.vs. with finite positive variance.

References:

1. Freedman, D., Pisani, R. and Purves, R. (2014). Statistics. 4th Edition. Norton & Comp.
2. Hanagal, D. D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.
3. Kendall, M.G. and Stuart, A. (1979). The Advanced Theory of Statistics, Vol. 2. Inference and Relationship. 4th Edition. Charles Griffin & Comp.
4. Kendall, M.G., Stuart, A. and Ord, J.K. (1994). The Advanced Theory of Statistics, Vol. 1. Distribution Theory. 6th Edition. Halsted Press (Wiley Inc.).
5. Kenney, J.F. and Keeping, E.S. (1947). Mathematics of Statistics. Part I. 2nd Edition. Chapman & Hall.
6. Kenney, J.F. and Keeping, E.S. (1951). Mathematics of Statistics. Part II. 2nd Edition. Chapman & Hall.
7. Tanner, M. (1990). An Investigation for a Course in Statistics. McMillan, New York.
8. Tanur, J.M. (1989) Statistics. A Guide to the Unknown. 3rd Edition, Duxbury Press.

9. Yule, G.U. and Kendall, M.G. (1973). An Introduction to the Theory of Statistics.
14th Edition. Charles Griffin & Comp.

ST-C-8: Statistical Inference-I

Learning Outcomes:

After going through this course, the students will get

- (a) a fundamental understanding of Parametric models for developing relevant inferences on associated parameters,
- (b) knowledge of point and interval estimation procedures and different methods of point estimation,
- (c) to understand the Cramer-Rao Inequality, Rao Blackwell and Lehmann Scheffe theorems and their applications in obtaining Minimum Variance Unbiased and Minimum Variance Bound estimators,
- (d) to work on several standard examples to help them understand the various inherent concepts.

Contents:

Unit I

Parametric model, parameter, random sample and its likelihood, brief idea of statistics and their sampling distributions

Point estimation: Properties of good estimators, mean square and minimum mean square error estimator, unbiasedness and minimum variance unbiased estimator, Cramer-Rao lower bound, amount of information.

Unit II

Consistency of estimators and sufficient conditions for consistency, relative efficiency of an estimator, unbiased estimator, sufficiency, factorization theorem, concept of complete sufficient statistics, Rao-Blackwell and Lehmann Scheffe theorems.

Unit III

Minimum variance unbiased estimators for the parameters of binomial, Poisson and normal families. Cramer-Rao inequality and MVB estimators.

Methods of estimation: Moments, maximum likelihood, minimum chi-square, least squares with examples, BAN and CAN estimators.

Unit IV

Point estimators of measures of location, dispersion, regression, correlation and other useful parameters. Concepts of confidence interval and confidence coefficient, confidence intervals for the parameters of univariate normal, two independent normal distributions and exponential distributions.

References:

1. Bickel, P.J. and Doksum, K.A. (2000). Mathematical Statistics, Second Edition, Prentice Hall.
2. Casella, G. and Berger, R.L. (2001). Statistical Inference, Second Edition, Cengage Learning.
3. Gupta, M.K., Gun, A.M., and Dasgupta, B. (2013). An Outline of Statistical Theory, Vol. 2. The World Press Publishers Pvt. Ltd., Calcutta.
4. Hogg, R.V., McKean J.W. and Craig, A.T. (2006). Introduction to Mathematical Statistics, Paperback Edition, Pearson.
5. Kale, B.K. (2005). A First Course on Parametric Inference. Alpha Science International Ltd.
6. Mood, A.M., Graybill, F.A. and Boes, D.C. (2011). Introduction to the Theory of Statistics, 3rd Edition., (Indian Edition), Tata McGraw-Hill Pub. Co. Ltd.
7. Rajagopalan, M. and Dhanavanthan, P. (2012). Statistical Inference. PHI Learning Pvt. Ltd., New Delhi.
8. Rao, C.R. (2009). Linear Statistical Inference and its Applications, Second Edition, Wiley.
9. Rohatgi, V. K. and Saleh A.K.M.E. (2008). An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.

ST-C-9: Sampling Techniques

Learning Outcomes

The students shall get

- (a) basic knowledge of complete enumeration and sample, sampling frame, sampling distribution, sampling and non-sampling errors, principal steps in sample surveys, limitations of sampling etc.,
- (b) introduced to various statistical sampling schemes such as simple, stratified, systematic and pps sampling,
- (c) an idea of conducting the sample surveys and selecting appropriate sampling techniques,
- (d) knowledge about comparing various sampling techniques.

Contents:

Unit I

Basic concepts: population and sample, census and sample survey, sampling frame, sampling distribution, standard error, sampling design, sampling and non-sampling errors, sample surveys, principles of sample survey, principal steps in sample survey, limitations of sampling, Sample survey versus complete enumeration survey.

Unit II

Simple Random Sampling (with and without replacement): Notations and terminology, various probabilities of selection. Random numbers tables and its uses. Methods of selecting simple random sample, lottery method, method based on random numbers. Estimates of population total, mean and their variances and standard errors, determination of sample size, simple random sampling of attributes.

Unit III

Probability proportional to size (PPS) sampling- Definition and terminology, cumulative total method and Lahiri's methods of selecting PPS sampling with and without replacement.

Systematic sampling: linear systematic sampling, estimates of population total, mean, and their variances and standard errors. Systematic sampling with linear trend. Circular systematic sampling, concepts and examples. Comparison of systematic sampling with simple random sampling.

Unit IV

Stratified random sampling: principles of stratification, notations, estimation of population mean and variances, cost function, allocation techniques, proportional and optimum allocations. Comparison of stratified sampling with simple random sampling.

References:

1. Ardilly, P. and Yves T. (2006). Sampling Methods: Exercise and Solutions. Springer.
2. Cochran, W.G. (2007). Sampling Techniques. (Third Edition). John Wiley & Sons, New Delhi.
3. Des Raj. (1976). Sampling Theory. Tata McGraw Hill, New York. (Reprint 1979)
4. Mukhopadhyay, P. (2007). Survey Sampling. Narosa Publisher, New Delhi.
5. Sampth, S. (2005). Sampling Theory and Methods, 2nd Edition, Alpha Science International Ltd.
6. Singh, D. and Choudhary, F.S. (1977). Theory and Analysis of Sample Survey Designs. Wiley Eastern Ltd, New Delhi. (Reprint 1986)
7. Sukhatme, P.V. and Sukhatme, B.V. (1970). Sampling Theory Surveys with Applications (Second Edition). Iowa State University Press.
8. Thompson, S.K. (2012). Sampling. John Wiley & Sons.

ST-C-10: Practical-III**Learning Outcomes:**

This course is based on ST-C-7, ST-C-8 and ST-C-9 and shall provide practical knowledge to the students on various topics such as small sample and large sample tests, bivariate probability distributions, estimation techniques and sampling techniques so that they can apply the relevant concepts to real life problems.

Learning outcomes of this course are same as those for ST-C-7, ST-C-8 and ST-C-9.

Contents:

1. Computation of covariance, coefficient of correlation, checking for independence and uncorrelatedness of two variables.
2. Test of significance for correlation coefficient. Fisher's z -transformation.
3. Categorical data: Tests of proportions, tests of association and goodness-of-fit using Chi-square test, Yates' correction.
4. Chi-square test for independence of attributes.
5. Student's t test for single mean and difference of means.
6. Computation of probabilities of events in bivariate probability distribution.
7. Finding marginal and conditional probability distributions.

8. Finding raw and central joint moments, joint m.g.f and joint c.g.f.
9. Problems on conditional expectation and conditional variance, Variance of linear combination of variables.
10. Checking the unbiasedness using suitable empirical example to prove that the sample mean is an unbiased estimator of population mean.
11. Checking the unbiasedness of sample variance and sample mean square as an estimator of population variance.
12. Graphically representing some standard discrete and continuous distributions for different values of their parameters and illustration how their shapes change.
13. Evaluation of sufficient statistic for some standard distributions.
14. Consistent estimators, efficient estimators, and relative efficiency of estimators.
15. Calculation of UMVUE.
16. Calculating the method of maximum likelihood for Binomial, Poisson and Normal parameters and obtaining variances of these estimates.
17. Calculation of asymptotic distribution of maximum likelihood estimators.
18. Calculations of Minimum chi-square, Moment estimators for standard distributions.
19. Calculation of Interval estimation, for mean and variance of normal distribution.
20. Simple Random Sampling – Lottery, random number method and other related problems, Sample size calculation.
21. Probability Proportional to Size Sampling: Cumulative total method & Lahiri's method.
22. Systematic Sampling – Problems related to Linear and Circular systematic sampling.
23. Problems related to Systematic sampling with Linear Trend.
24. Stratified Random Sampling – Problems related to Different types of allocation.
25. Stratified Random Sampling – Problems related to Optimum allocation and other related problems.
26. Sample size calculations

References:

As specified in ST-C-7, ST-C-8 and ST-C-9.

ST-C-11: Regression Analysis**Learning Outcomes:**

The students shall

- (a) know about correlation and regression techniques, the two very powerful tools in statistics,
- (b) get an idea of Linear, Polynomial and Multiple Linear regression,
- (c) learn about regression diagnostics, multicollinearity, residual plots and estimation and tests for regression coefficients.
- (d) study concept of coefficient of determination and inference on partial and multiple correlation coefficients.

Contents:**Unit I**

Correlation: Bivariate data, Scatter diagram and interpretation. Concept of correlation between two variables, positive correlation, negative correlation, no correlation. Covariance between two variables: Definition, computation, effect of change of origin and scale.

Unit II

Karl Pearson's coefficient of correlation (r): Definition, computation for ungrouped data and interpretation. Properties : (i) $-1 \leq r \leq 1$ (with proof), (ii) Effect of change of origin and scale (with proof).

Spearman's rank correlation coefficient: Definition, computation and interpretation (without ties), Spearman's rank correlation coefficient (derivation of formula in case of without ties). In case of ties, compute Karl Pearson's correlation coefficient between ranks. (Spearman's rank correlation coefficient formula with correction for ties not expected.). Examples and Problems.

Unit III

Linear Regression: Meaning of regression, difference between correlation and regression, simple linear regression model, Estimation of regression parameters by least squares method (fitting of regression model), Interpretation of parameters. Concept of residual, Residual plots, comparison of two models on the basis of residual sum of squares. Regression diagnostics. Tests for regression coefficients.

Polynomial regression: Estimation of regression parameters by least squares method, Interpretation of parameters. Concept of residual, Residual plots.

Unit IV

Estimation of regression parameters by least square method, Interpretation of parameters.

Determination of appropriate model by plotting Y versus X.

Multiple linear regression: Estimation of regression parameters by least square method,

Interpretation of parameters. Concept of coefficient of determination. Multicollinearity.

Inference on partial and multiple correlation coefficients.

References:

1. Draper, N. R. and Smith, H. (1998). Applied Regression Analysis. 3rd Edition. John Wiley.
2. Hosmer, D. W., Lemeshow, S. and Sturdivant R.X. (2013). Applied Logistic Regression, Wiley Blackwell.
3. Montgomery, D. C., Peck, E. A. and Vining, G. G. (2013). Introduction to Linear Regression Analysis. 5th Edition. Wiley.
4. Neter, J., Kutner, M. H., Nachtsheim, C.J. and Wasserman, W. (1996). Applied Linear Statistical Models, 4th Edition, Irwin USA.

ST-C-12: Statistical Inference-II

Learning Outcomes:

The course will provide the students with a knowledge of

- (a) advanced level topics in statistical inference on testing of statistical hypotheses for both randomized and non-randomized tests,
- (b) using Neyman Pearson Lemma and finding Uniformly Most Powerful Test,
- (c) likelihood ratio test and its applications,
- (d) confidence interval estimation and their relationships with testing,
- (e) order statistics and their distributions,
- (f) Wald's Sequential Probability Ratio Test and concepts of ASN and OC functions,
- (g) Sequential estimation with examples based on standard probability distributions,
- (h) statistical decision problem including the concept of loss and risk functions, Bayes and Minimax Decision rules.

Contents:**Unit I**

Statistical hypotheses, critical region, size and power of a test, most powerful test, randomized and non-randomized test, Neyman Pearson lemma and its applications, uniformly most powerful unbiased test, likelihood ratio test and its applications, functions of UMP with simple illustration.

Unit II

Confidence Intervals: Criteria for goodness, pivotal quantities, relationship with tests of hypotheses, illustrations.

Theory of order statistics: Formulation of the problems, order statistics and their distributions.

Unit III

Tests and confidence intervals for population quantiles. Estimation of location and scale parameters.

Sequential Analysis: Need for sequential tests. Wald's SPRT, ASN, OC function. Brief idea of sequential estimation, examples based on normal, Poisson, binomial and exponential distributions.

Unit IV

Elements of decision problems: Loss function, risk function, estimation and testing viewed as decision problems. Bayes and minimax rules. Examples based on loss function, risk function, estimation and testing problems.

References:

1. Bickel, P.J. and Doksum, K.A. (2000). Mathematical Statistics, Second Edition, Prentice Hall.
2. Casella, G. and Berger, R.L. (2001). Statistical Inference, Second Edition, Cengage Learning.
3. D'Abrera H.J.M. and Lehmann, E. L. (2006). Non-parametrics: Statistical Methods Based on Ranks. Prentice Hall.
4. Gupta, M.K., Gun, A.M., and Dasgupta, B. (2013). An Outline of Statistical Theory, Vol. 2. The World Press Publishers Pvt. Ltd., Calcutta.
5. Hogg, R.V., McKean J.W. and Craig, A.T. (2006). Introduction to Mathematical Statistics, Paperback Edition, Pearson.

6. Kale, B.K. (2005). A First Course on Parametric Inference. Alpha Science International Ltd.
7. Mood, A.M., Graybill, F.A. and Boes, D.C. (2011). Introduction to the Theory of Statistics, 3rd Edition., (Indian Edition), Tata McGraw-Hill Pub. Co. Ltd.
8. Rajagopalan, M. and Dhanavanthan, P. (2012). Statistical Inference. PHI Learning Pvt. Ltd., New Delhi.
9. Rao, C.R. (2009). Linear Statistical Inference and its Applications, Second Edition, Wiley.
10. Rohatgi, V. K. and Saleh A.K.M.E. (2008). An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.

ST-C-13: Numerical Analysis

Learning Outcomes:

The students shall

- (a) demonstrate knowledge of different numerical methods , essential for providing Mathematical support to the Statisticians where intractability becomes severe,
- (b) be able to learn various difference, interpolation formulae,
- (c) be in a position to find solutions to equations using Bisection, Newton Raphson and Regula Falsi Methods,
- (d) handle numerical differentiation and integration,
- (e) be able to find solutions to difference equations of first order and linear difference equations with constant coefficients.

Contents:

Unit I

Numerical Analysis: Factorial with positive and negative index. Operators: Shift operator, forward difference, backward difference, central difference, average, differential and inter-relations between them. Finite differences of order n , divided differences of order n and interpolation.

Unit II

Newton's forward, backward and divided difference interpolation formulae with error term.

Lagrange's interpolation formula. Central difference formulae: Gauss and Stirling's formulae.

Unit III

Inverse interpolation: Lagrange's inverse interpolation formula, Method of successive approximation and method of reversion of series. Summation of finite series. Finding Root of an Equation: Bisection, Regula Falsi and Newton Raphson Methods. Numerical differentiation.

Unit IV

Numerical integration: Newton-Cote's integration formula, Trapezoidal rule, Simpson's one-third rule, Simpson's three-eighth rule and Weddle's rule with error term. Euler-Maclaurin's summation formula. Stirling's approximation to factorial n . Solution of difference equations of first order with variable coefficients and linear difference equations with constant coefficients.

References:

1. Bradie, B. (2006). A friendly introduction to Numerical Analysis, Pearson Education, India.
2. Gerald, C. F. and Wheatly, P. O. (2005). Applied Numerical Analysis, Pearson Education, India.
3. Hilderbrand, F.B. (1987). Introduction to Numerical Analysis, Second Edition, Dover Publications.
4. Jain, M.K., Iyengar, S.R. K. and Jain, R.K. (2007). Numerical Methods for Scientific and Engineering Computation, Second Edition, Wiley Eastern Ltd.
5. Krishnamoorthy, E.V. and Sen, S.K. (2001). Numerical Algorithms: computations in Science and Engineering. East West Press, New Delhi.
6. Sastry, S.S. (2000). Introductory Methods of Numerical Analysis, 3rd edition, Prentice Hall of India Pvt. Ltd., New Delhi.
7. Saxena, H.C. (2005). Finite Differences and Numerical Analysis, 15th Revised Edn. (Reprint). S. Chand & Co.
8. Scarborough, J.B. (1966). Numerical Mathematical Analysis, 6th Edition. Oxford and IBH.

ST-C-14: Practical-IV

Learning Outcomes:

This course is based on ST-C-11, ST-C-12 and ST-C-13 and at the end of the course, students shall be able to use and apply regression techniques, obtain UMP tests and demonstrate knowledge of numerical methods. Learning outcomes of this course are same as those for ST-C-11, ST-C-12 and ST-C-13.

Contents:

1. Calculation of coefficient of correlation.
2. Calculation spearman rank correlation
3. Simple linear regression, residuals, estimate of intercept, regression coefficients.
4. Residual plots, regression diagnostics.
5. Multiple linear regression and regression estimates.
6. Calculation of multiple correlation,
7. Calculation of partial correlation.
8. Polynomial regression and regression estimates.
9. Calculation of Type I and Type II error probabilities.
10. Calculation of size of critical region, power of the test for the mean of a normal distribution with known and unknown variance and plotting graph of the power function.
11. Calculation of size of most powerful critical region (NP lemma).
12. Evaluating shortest confidence interval for mean of normal distribution when variance is known/unknown.
13. Evaluating shortest confidence interval for variance of normal distribution when mean is known/unknown.
14. Calculation of power of the test for the Bernoulli distribution with probability (p) in case of simple hypothesis and power curves and plotting the graph of the power function.
15. Calculation of likelihood ratio test (LRT) for simple hypothesis.
16. Calculation of likelihood ratio test (LRT) for composite hypothesis.
17. Calculation of asymptotic properties of LRT.

18. Sequential probability ratio test for the given hypothesis, esp. For Bernoulli trials. Calculation of ASN and OC curve.
19. Newton's forward, backward and divided difference interpolation formulae with error term.
20. Lagrange's interpolation formula, Central difference formulae.
21. Lagrange's inverse interpolation.
22. Trapezoidal rule, Simpson's one-third rule and Simpson's three-eighth rule.
23. Weddle's rule with error term.
24. Stirling's approximation to factorial n.
25. Euler-Maclaurin's summation formula.
26. Solution of difference equations of first order with variable coefficients and linear difference equations with constant coefficients.

References:

As specified in ST-C-11, ST-C-12 and ST-C-13.

ST-C-15: Optimization Techniques**Learning Outcomes:**

The students shall get exposed to

- (a) graphical and simplex method of solving linear programming problem (LPP) for finding degenerate, unbounded, alternate and infeasible solutions,
- (b) post-optimality: addition of constraints, change in requirement vector, addition of new activity and change in cost vector,
- (c) use of duality to solve a LPP,
- (d) obtaining solution of a transportation problem by North West corner method, Matrix Minima method, Vogel's method,
- (e) Hungarian Method for solving assignment problems,
- (f) game theory for graphical solution of $m \times 2$ or $2 \times n$ rectangular game and mixed strategy,
- (g) networking problem using minimal spanning tree and shortest route,
- (h) optimal inventory policy for EOQ model and its variations.
- (i) solving quantity discounts model with price breaks.

Contents:**Unit I**

Definitions and scope of operations research, different types of models in operations research – their construction and general method of solution.

Elements of linear programming problem (LPP): Canonical and standard forms, formulation of LPP, graphical method to solve two variable LPP, solution of LPP using simplex procedure, use of artificial variables in LPP, generation of extreme point solutions, principle of duality in LPP, statement and proof of duality theorem, simple problems based on duality theorem.

Unit II

Allocation Models: Transportation problem (T.P.), different methods of finding initial feasible solution of a T.P., UV method of finding optimal solution of a T.P., solution of assignment problem using Hungarian method.

Unit III

Inventory Control: Definitions of various costs involved in inventory control. ABC inventory system, characteristics of inventory system. Deterministic Economic Lot Size problems, EOQ model and its variations (with and without shortages). Quantity discount model with price breaks.

Unit IV

Theory of games: Two person zero-sum games, pure and mixed strategies, saddle point, minimax-maximin principle of rectangular games, games without saddle point, dominance and modified dominance principles, graphical solution of $2 \times N$ and $M \times 2$ games, reduction of game problems to a Linear programming problem. Networking: Shortest route and minimal spanning tree problem.

References:

1. Gass, S. I. (2010). Linear Programming, Methods and Applications, 5th Ed., Dover Books.

2. Hadley, G. (2002). Linear programming. Narosa.
3. Hiller, F.S. and Liebermann, G.J. (2009). Introduction to Operations Research, McGraw Hill.
4. McKinsey, J.C.C. (2003). Introduction to the Theory and Games. Dover Books.
5. Swaroop, K., Gupta, P.K. and Singh, M.M. (2005). Operations Research. Sultan Chand and Sons.
6. Taha, H.A. (2014). Operations Research, Ninth Edition, Pearson Education India.

ST-C-16: Statistical Quality Control and Reliability

Learning Outcomes:

The students will be able to

- (a) construct group control chart,
- (b) draw charts for variables and attributes,
- (c) draw CUMSUM chart,
- (d) understand single and double sampling inspection plans, OC and ASN functions,
- (e) get introduced to notion of censored data, Type I, Type II and random censoring schemes,
- (f) get idea of important lifetime distributions such as for exponential, Weibull, gamma and lognormal distributions.
- (g) compute MLEs of exponential distribution for complete and censored data,
- (h) compute MLEs of lognormal distributions,
- (i) compute MLEs of gamma and Weibull distributions using iterative procedure,
- (j) fit exponential and Weibull distributions for a given lifetime dataset,
- (k) find interval estimates for the parameters of exponential, Weibull, gamma and lognormal distributions.
- (l) Test reliability hypotheses for exponential and Weibull distributions,
- (m) evaluate system reliability for series, parallel, k out of n systems,

Contents:

Unit I

Introduction to SQC. Quality of a product, need for quality control, basic concept of process control, process capability and product control, general theory of control charts, causes of variation in quality, control limits, sub grouping summary of out of control criteria. Charts for attributes: p chart, np chart, c-chart, V chart. Charts for variables: \bar{R} , (\bar{R}, R) , (\bar{R}, σ) charts. Single and double sampling inspection plans, OC and ASN functions.

Unit II

Life testing and reliability theory: Basic concepts of life testing experiments, reliability, hazard function, mean time to failure and their relationships. Elementary notion of censored data, type I, type II and random censoring schemes, Poisson process.

Unit III

Parametric distributions: exponential, Weibull, gamma, and lognormal as life time distributions, point and interval estimation procedures for the above distributions. Testing reliability hypothesis for exponential and Weibull distributions.

Unit IV

System Reliability: Evaluation of reliability function and mean time to system failure for Series, Parallel, k-out of-n, series-parallel, parallel-series and Bridge system configurations.

References:

1. Banks, J. (1989). Principles of Quality Control. John Wiley & Sons, New York.
2. Barlow, R. E. and Proschan, F. (1974). Statistical Theory of Reliability and Life Testing Probability Models, Holt Rinehart and Winston.
3. Duncan, A.J. (1974). Quality Control and Industrial Statistics, 4th Edition, Taraporewala & Sons.
4. Montgomery, D.C. (2012). Introduction to the Statistical Quality Control, 7nd Edition, John Wiley & Sons.
5. Schilling, E.G. and Ott, E.R. (1975). Process Quality Control. McGraw Hill.

ST-C-17: Practical-V

Learning Outcomes:

This course is based on ST-C-15 and ST-C-16 and at the end of the course, students shall be able to draw different types of control charts for variables and attributes. They will also be able to understand the practical applicability of single and double sampling inspection plans.

The students will be able to get an idea of reliability and hazard function and how to discriminate among the important lifetime distributions based on hazard function.

Learning outcomes of this course are similar to those of ST-C-15 and ST-C-16.

Contents:

1. Construction of group control chart.
2. Draw an R chart and a modified R chart.
3. CUMSUM chart.
4. Computation of MLE of exponential, lognormal distributions.
5. Computation of MLE of exponential distribution for censored data.
6. Computation of MLE of Gamma and Weibull distributions using iterative procedure.
7. Fitting of Exponential and Weibull distributions for a given lifetime dataset.
8. Plotting of Survival function and hazard rate function for exponential, Weibull, Gamma and lognormal distributions.
9. Graphical and simplex method of solving linear programming problem (LPP) for degenerate solution, unbounded solution, alternate solution and infeasible solution.
10. Post-optimality: addition of constraints, change in requirement vector, addition of new activity and change in cost vector.
11. Obtaining solution of LPP using simplex method. Use of duality to solve a LPP.
12. Obtaining solution of a transportation problem by North west corner method, Matrix Minima method, Vogel's method.
13. Practical based on assignment problems.
14. Practical based on game theory: graphical solution of $m \times 2$ or $2 \times n$ rectangular game, mixed strategy.
15. Networking problem: minimal spanning tree problem, shortest route problem.
16. To find optimal inventory policy for EOQ model and its variations.
17. To solve all unit quantity discounts model.

References:

As specified in ST-C-15 and ST-C-16.

ST-C-18: Design of Experiments**Learning Outcomes:**

The students will be in a position to

- (a) carry out one way and two way Analysis of Variance (ANOVA),
- (b) understand the basic terms used in design of experiments,
- (c) use appropriate experimental designs to analyze the experimental data,
- (d) analyze 2^2 and 2^3 factorial experiments,
- (e) apply Multiple range tests, the *LSD* test or the multiple t–test, Student-Newman-Keuls test, Duncan’s multiple range test, Tukey’s test, Multiple F tests, Fisher’s least significant difference test, Scheffe’s test,
- (f) give statistical interpretation of the experimental results obtained.

Contents:**Unit I**

Analysis of variance: Definition, assumption for ANOVA test, one-way and two-way classifications for fixed effect model with one observation per cell. Introduction to design of experiments: terminology, experiment, treatment, experimental units, blocks, experimental error, replication, precision and accuracy, need for design of experiment, size and shape of plots and blocks.

Unit II

Fundamental principles of design of experiments: Randomization, Replication and Local control, Completely randomized design(CRD), Randomized Complete Block Design(RCBD), Latin square design(LSD) and their layout and analyses. Missing plot technique for RCBD and LSD, missing plot techniques for one observation per cell in RCBD. Analysis of covariance in CRD and RCBD with one concomitant variable: concepts and examples, transformations.

Unit III

Multiple range tests, the *LSD* test or the multiple t – test, Student-Newman-Keuls test, Duncan’s multiple range test, Tukey’s test, comments on multiple range test. Multiple F tests, Fisher’s least significant difference test, Scheffe’s test, comments on multiple F tests.

Unit I V

Factorial experiments: Definition, advantages and limitations, main effects and interaction effects, concepts of 2^2 and 2^3 factorial experiments, Yate's procedure for computation of factorial effect totals and their analyses.

References:

1. Cochran, W. G. and Cox, G. M. (1957). Experimental Design. John Wiley & Sons, New York.
2. Das, M. N. and Giri, N. S. (1986). Design and Analysis of Experiments (2^{nd} Edition). Wiley.
3. Dean, A. and Voss, D. (1999). Design and Analysis of Experiments. Springer-Verlag, New York.
4. Federer, W.T. (1955). Experimental Design: Theory and Applications. Oxford & IBH Publishing Company, Calcutta, Bombay and New Delhi.
5. Joshi, D.D. (1987). Linear Estimation and Design of Experiments. New Age International (P) Ltd. New Delhi.
6. Montgomery, D.C. (2017). Design and analysis of Experiments, 9^{th} Edition. John Wiley & Sons.

ST-C-19: Non-Parametric Inference

Learning Outcomes:

This course will help the students to

- (a) use different nonparametric/distribution-free tests when data don't meet the assumptions of parametric test,
- (b) understand importance of different non-parametric test procedures, their applications and interpretation,
- (c) analyse categorical data using logistic regression models.

Contents:

Unit I

Introduction, concepts of nonparametric/distribution free method: one-sample case: Binomial test, Chi-Square Goodness-of-fit test, Kolmogorov–Smirnov one sample test, One-sample runs test for randomness, sign test, Wilcoxon's signed rank test, theory and applications.

Unit II

Two-sample case: median test, Wilcoxon-Mann-Whitney test, Mood test, Freund-Ansari test, Kolmogorov-Smirnov two-sample test, Siegel-Tukey test for scale differences, theory & applications.

Unit III

The Cochran Q test for k related samples: Friedman test by ranks, extended median test, Kruskal-Wallis one-way analysis of variance by ranks, Jonckheere test for ordered alternatives. Theory and applications of these tests.

Unit IV

Concept of Indicator Variables, categorical data analysis, logistic regression models, models with binary response. Theory and Applications

References:

1. Gibbons, J.D. and Chakraborty, S. (2010). Nonparametric Statistical Inference, Chapman and Hall/CRC.
2. Kloeke, J. and McKean, J.W. (2014). Nonparametric Statistical Methods Using R. Chapman & Hall/CRC Press.
3. Montgomery, D.C., Peack, E.A. and Vining, G.G. (2006). Introduction to Linear Regression Analysis. 3rd Edition, Wiley India Pvt. Ltd., New Delhi.
4. Neuhäuser, M. (2017). Nonparametric Statistical Tests. A Computational Approach, Chapman and Hall/CRC.
5. Rajagopalan, M. and Dhanavanthan, P. (2012): Statistical Inference. PHI Learning Pvt. Ltd., New Delhi.
6. Sheskin, D.J. (2011). Handbook of Parametric and Nonparametric Statistical procedure. (Fifth Edition), Chapman and Hall/CRC.
7. Siegel, S, J. and Castellan, N.Jr. (1998). Nonparametric Statistics for the Behavioral Sciences. McGraw-Hill.
8. Sprent, P. and Smeeton, N.C. (2007). Applied Nonparametric Statistical Methods, Chapman & Hall/CRC Press.
9. Takezawa, K. (2005). Introduction to Nonparametric Regression. Wiley-Inter science; 1st edition.

10. Wayne, W. D. (2000). Applied Nonparametric Statistics, 2nd Edition. Cengage Learning.

ST-C-20: Practical – VI

Learning Outcomes:

This course is based on ST-C-18 and ST-C-19 and at the end of the course, students shall be able to analyse data using various non-parametric tests. Also, the students will be in a position to visualize the scope of experimental designs in getting valid and efficient results. As a result, they will decide to select an appropriate experimental design and analyse the same to interpret the results so obtained.

Learning outcomes of this course are similar to those of ST-C-18 and ST-C-19.

Contents:

The following practicals are to be carried. In all the practicals description of each method and interpretation of the results are important.

1. One-way analysis of variance, Multiple range tests – The LSD test or the multiple t – test, Student-Newman-Keuls test, Duncan’s multiple range test, Tukey’s test.
2. Multiple F tests- Fisher’s least significant difference test, Scheffe’s test, Comments on multiple F tests.
3. Completely Randomised Design (CRD), Randomised Complete Block Design (RCBD) – methods, analysis and interpretation.
4. Latin Square Design – methods, analysis and interpretation.
5. Analysis of covariance in CRD and RCBD.
6. Missing plot technique (single value) in RCBD.
7. Data Transformation – Logarithmic, Square-Root and Arc Sine.
8. Analysis and Interpretations of 2^2 and 2^2 factorial experiment using Yate’s procedure.
9. Single-sample case – Binomial test, Chi-Square goodness-of-fit test, The Kolmogorov – Smirnov one sample test.
10. The one-sample runs test for randomness – The Sign test – Wilcoxon’s Signed Rank Test.
11. Two-Sample Case – Median test, Wilcoxon-Mann-Whitney U-test, Mood test, Freund-Ansari test.
12. Kolmogorov – Smirnov two-sample test, Siegel-Tukey test for scale differences.

13. The Cochran Q test for k related samples, Friedman test by ranks, extended median test.
14. Kruskal-Wallis One-Way Analysis of variance by ranks.
15. Jonckheere test for ordered alternatives. Theory and applications of these tests.
16. Logistic Regression Model.

References:

As specified in ST-C-18 and ST-C-19.

Syllabi of Discipline Specific Electives (DSE) ST-DSE-1: Time Series Analysis

Credits 6 (Theory: 4 + Practical: 2)

Learning Outcomes:

This course is meant to acquaint the students with some important but useful concepts on topics in time series analysis so that the students can get an important background material for taking up an advanced course in financial econometrics and data analysis. After completion of this course, the students will know about

- (a) time series data, its applications to various fields and components of time series,
- (b) fitting and plotting of various growth curves such as modified exponential, Gompertz and logistic curve,
- (c) fitting of trend by Moving Average method,
- (d) measurement of Seasonal Indices by Ratio-to-Trend , Ratio-to-Moving Average and Link Relative methods,
- (e) calculation of variance of random component by variate component method,
- (f) forecasting by exponential smoothing and short term forecasting methods such as Box Jenkins Method and Bayesian forecasting,
- (g) weak stationarity, autocorrelation and correlogram,
- (h) applications to real data by means of laboratory assignments.

Contents (Theory):**Unit I**

Introduction to times series data, application of time series from various fields, Components of a times series, Decomposition of time series. Trend: Estimation of trend by free hand curve method, method of semi averages, fitting a various mathematical curve, and growth curves.

Unit II

Trend Cont.: Method of moving averages. Detrending. Effect of elimination of trend on other components of the time series. Seasonal Component: Estimation of seasonal component by Method of simple averages, Ratio to Trend.

Unit III

Seasonal Component count: Ratio to Moving Averages and Link Relative method, Deseasonalization. Cyclic Component: Harmonic Analysis. Some Special Processes: Moving-average (MA) process and Autoregressive (AR) process of orders one and two, Estimation of the parameters of AR (1) and AR (2) – Yule-Walker equations.

Unit IV

Random Component: Variate component method. Forecasting: Exponential smoothing methods, Short term forecasting methods: Brown's discounted regression, Box-Jenkins method and Bayesian forecasting. Stationary Time series: Weak stationarity, autocorrelation function and correlogram of moving average.

Contents (Practical):

1. Fitting and plotting of modified exponential curve.
2. Fitting and plotting of Gompertz curve.
3. Fitting and plotting of logistic curve.
4. Fitting of trend by Moving Average method.
5. Measurement of Seasonal Indices Ratio-to-Trend method.
6. Measurement of Seasonal Indices Ratio-to-Moving Average method.
7. Measurement of seasonal indices Link Relative method.
8. Calculation of variance of random component by variate difference method.
9. Forecasting by exponential smoothing.
10. Forecasting by short term forecasting methods.

References:

1. Box, G.E.P., Jenkins, G.M., Reinsel, G.C. and Ljung, G.M. (2015). Time Series Analysis: Forecasting and Control. 5th Edition. John Wiley & sons, Inc.
2. Brockwell, P.J. and Davis, R.A. (2003). Introduction to Time Series Analysis. Springer.
3. Chatfield, C. (2001). Time Series Forecasting., Chapman & Hall.
4. Fuller, W.A. (1996). Introduction to Time Series. 2nd Edition. Wiley.
5. Kendall, M.G. and Ord, J.K. (1990). Time Series. 3rd edition. Edward Arnold.
6. Montgomery, D.C., Jennings, C.L. and Kulahci, M. (2012). Introduction to Time Series Analysis and Forecasting, John Wiley.
7. Mukhopadhyay, P. (2011). Applied Statistics, 2nd ed. Revised reprint, Books and Allied Pvt. Ltd.

ST-DSE-2: Actuarial Statistics**Credits 6 (Theory: 4 + Practical: 2)****Learning Outcomes:**

This course is framed to equip the students with concepts of actuarial science and different premium models. After opting for this course, the students will be equipped with knowledge about

- (a) modelling of individual and aggregate losses.
- (b) fitting of distributions to claims data, deductibles and retention limits, proportional and excess-of-loss reinsurance.
- (c) Risk models: models for individual claims and their sums.
- (d) finding distribution of aggregate claims, compound distributions and their applications,
- (e) applications of credibility theory.
- (f) finding of survival function, curate future lifetime, force of mortality.
- (g) handling problems on joint life and last survivor status and multiple decrement model.
- (h) mean and variance of various continuous and discrete payments for assurance and annuity contracts.
- (i) calculation of various payments from life tables using principle of equivalence, net premiums, prospective and retrospective provisions/reserves,

- (j) real illustrations for the concepts mentioned above through laboratory assignments.

Contents (Theory):

Unit I

Probability Models and Life Tables, Loss distributions: modelling of individual and aggregate losses, moments, fitting distributions to claims data, deductibles and retention limits, proportional and excess-of-loss reinsurance. Risk models: models for individual claims and their sums, Distribution of aggregate claims, Compound distributions and applications, Introduction to credibility theory.

Unit II

Survival function, curtate future lifetime, force of mortality. Multiple life functions, joint life and last survivor status. Multiple decrement model. Life Contingencies: Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor.

Unit III

Assurance and annuity contracts: definitions of benefits and premiums, various types of assurances and annuities, present value, formulae for mean and variance of various continuous and discrete payments.

Unit IV

Calculation of various payments from life tables: principle of equivalence, net premiums, prospective and retrospective provisions/reserves.

Contents (Practical):

- (a) modelling of individual and aggregate losses.
- (b) moments, fitting distributions to claims data, deductibles and retention limits, proportional and excess-of-loss reinsurance. Risk models: models for individual claims and their sums.
- (c) finding distribution of aggregate claims, compound distributions and their applications,
- (d) applications of credibility theory.
- (e) finding survival function, curate future lifetime, force of mortality.
- (f) problems on joint life and last survivor status and multiple decrement model.

- (g) finding mean and variance of various continuous and discrete payments for assurance and annuity contracts.
- (h) Calculation of various payments from life tables using principle of equivalence, net premiums, prospective and retrospective provisions/reserves.

References:

1. Boland, P. (2007). Statistical and Probabilistic Methods in Actuarial Science. Chapman and Hall/CRC.
2. Borowaik, D.S. and Shapiro, A. F. (2013). Financial and Actuarial Statistics: An Introduction. 2nd Edition. Marcel Dekker Inc., New York-Basel.
3. Bowers, N. L., Gerber H. U., Hickman, J. C., Jones, D. A. and Nesbitt, C. J. (1997). Actuarial Mathematics, 2nd Edition, Society of Actuaries, USA.
4. Deshmukh, S.R. (2005). Actuarial Statistics: In Introduction Using R. Narosa Publishing House, New Delhi.
5. Klugman, S. A., Panjer, H. H. and Willmot, G. E. (2013). Loss Models: Further Topics, 4th Edition. Wiley-Interscience.
6. Promislow, S. D. (2014). Fundamentals of Actuarial Mathematics. 3rd Edition. Wiley.

ST-DSE-3: Survival Analysis**Credits 6 (Theory: 4 + Practical: 2)****Learning Outcomes:**

The course gives the application of statistics in handling survival data. The students will know about concepts of

- (a) Type-I (time), Type-II (order) and random censoring,
- (b) Survival Function, Failure rate, mean residual life, Total time on Test,
- (c) applications of exponential, gamma, Weibull distributions, lognormal, Pareto, linear failure rate distributions to lifetime data,
- (d) ageing properties of IFR, IFRA, DMRL, NBU, NBUE and HNBUE and Dual classes.
- (e) Actuarial and Kaplan –Meier estimator of survival function,
- (f) Cox’s proportional hazards and competing risk models,
- (g) tests for exponentiality,

- (h) Real lifetime data implementation of various concepts as outlined above through practical assignments.

Contents (Theory):

Unit I

Concepts of Type-I (time), Type-II (order) and random censoring, Survival Function, Failure rate, mean residual life and their elementary properties. Total time on Test, bathtub failure rate.

Life distributions: exponential, gamma, Weibull, lognormal, Pareto, linear failure rate.

Unit II

Ageing classes (IFR, IFRA, DMRL, NBU, NBUE and HNBUE) and their properties, Dual classes, Interrelations between different ageing classes.

Unit III

Estimation of survival function – Actuarial estimator, Kaplan –Meier estimator, Cox’s proportional hazards model, competing risks model.

Unit IV

Definition of U statistics, tests for exponentiality versus positive ageing class such as IFR, IFRA, NBU.

Contents (Practical):

1. Examples of Type-I (time), Type-II (order) and random censoring.
2. Finding Survival Function, Failure rate, mean residual life, Total time on Test.
3. Applications of exponential, gamma, Weibull distributions.
4. Applications of lognormal, Pareto, linear failure rate distributions.
5. Problems on ageing properties, IFR, IFRA, DMRL, NBU, NBUE and HNBUE and Dual classes.
6. Examples for Actuarial estimator and Kaplan –Meier estimator of survival function.
7. Applications of Cox’s proportional hazards model.
8. Applications of competing risks model.
9. Tests for exponentiality.

References:

1. Cox, D.R. and Oakes, D. (1984). Analysis of Survival Data. Taylor and Francis.
2. Crowder, M. J. (2001). Classical Competing Risks. Chapman & Hall/CRC Press, London.
3. Deshpande, J. V. and Purohit, S.G. (2015). Lifetime Data: Statistical Models and Methods. 2nd Edition. World Scientific.
4. Gross, A.J. & Clark, V.A. (1976). Survival Distributions-Reliability Applications in Bio- medical Sciences. John Wiley and Sons.
5. Hanagal, D. D. (2011). Modeling Survival Data Using Frailty Models. Chapman & Hall. New York.
6. Kalbfleisch, J.D. and Prentice, R.L. (1980). The Statistical Analysis of Failure Time Data. John Wiley and Sons.
7. Miller, R.G. (1998). Survival Analysis. Second Edition. Wiley Interscience.

ST-DSE-4: Applied Statistics**Credits 6 (Theory: 4 + Practical: 2)****Learning Outcomes:**

After going through this course, the students will have an idea of

- (a) income distributions and their fitting in real life situations,
- (b) commonly used measures of demography pertaining to its three basic aspects, viz. the fertility, mortality and migration,
- (c) various data collection methods enabling them to have a better insight in policy making, planning and systematic implementation,
- (d) Construction and implication of life tables,
- (e) Population growth curves, population estimates and projections,
- (f) Real data implementation of various demographic concepts as outlined above through practical assignments.

Contents (Theory):**Unit I**

Analysis of income and allied size distributions: Pareto and log-normal distributions, genesis, specification and estimation, Lorenz curve, Gini coefficient.

Demand analysis: Classification of commodities, Engel curve analysis using cross-section and time series data, Engel curves incorporating household characteristics, demand projection, specific concentration curves.

Unit II

Sources of demographic data, census, registration, ad hoc surveys, hospital records, demographic profiles of the Indian census.

Measurement of Mortality and Life Table: Crude death rate, Standardized death rates, Age-specific death rates, Infant Mortality rate, Death rate by cause, Complete life table and its main features, Uses of life table.

Unit III

Measurement of Fertility: Crude birth rate, general fertility rate, age specific birth rate, total fertility rate, gross reproduction rate, net reproduction rate. Rates and ratios. Measures of mortality. Life Table – construction and applications.

Unit IV

Stable and stationary population. Measures of fertility and reproduction. Indian data. Standardization of vital rates. Population growth curves, population estimates and projections. Measures of migration. Use of demographic data for policy formulation.

Contents (Practical):

1. Fitting of Engel's curve and calculation of income elasticity of demand.
2. Fitting of Pareto's law for income distribution for a given Income dataset, for entire range as well as specific range.
3. Fitting of a Lorentz curve for a data and computation of the concentration ratio using graphical method.
4. Calculation of Crude birth rate; General fertility rate; Age specific fertility rate; Total fertility rate; Gross reproduction rate; Net reproduction rate.
5. Calculation of Infant mortality rate, Crude death rate, Age specific death rates.
6. Computation of standardized birth and death rates.

7. Construction of life tables.
8. Population growth curves, population estimates and projections.

References:

1. Benjamin, B. (1959). Health and Vital Statistics. Allen and Unwin.
2. Cramer, J.S. (1969). Empirical Econometrics. North Holland Pub. Co.
3. Karmel, P.H. and Polasek, M. (1957). Statistics for Economists. Pitman Publishing.
4. Klein, L.R. (1962). An Introduction to Econometrics. Prentice Hall.
5. Mishra, B.D. (2004). An Introduction to the Study of Population. South Asian Publishers.
6. Mukhopadhyay, P. (1994). Applied Statistics. New Central Book Agency Pvt. Ltd. Calcutta.
7. Ramkumar, R. (1986). Technical Demography. John Wiley & Sons.
8. Srinivasan, K. (1998). Demographic Techniques and Applications. Sage Publications.
9. Srivastava O.S. (1983). A Text Book of Demography. Vikas Publishing House.
10. Shryock, H.S. (1971). The Methods and Materials in Demography. U.S. Bureau of Census.

ST-DSE-5: Financial Statistics**Credits 6 (Theory: 4 + Practical: 2)****Learning Outcomes:**

The course is designed to provide the students with

- (a) various Mathematical and Statistical concepts applicable in the area of Financial Statistics,
- (b) some elementary concepts in Financial Statistics leading to generalized cash flow models,
- (c) Some advanced level concepts such as compound interest function including level and non-level annuities, continuous payment cashflows etc.,
- (d) Investment and risk characteristics involved with different types of assets,
- (e) Some simple stochastic models for investment returns etc.,
- (f) Sufficient practical training on relevant concepts by means of laboratory assignments.

Contents (Theory):**Unit I**

Accumulation Function, Simple interest, compound interest, Generalized Cash- flow model, Concepts of compound interest and discounting, Nominal Interest rates or discount rates in terms of different time periods, Force of interest, Present Value of Future Payments.

Unit II

Definition of compound interest functions including annuities certain, Level payment annuities, Level payment perpetuities, Repayment mode (mthly), Non-level payment annuities and perpetuities: Geometric, Increasing and Decreasing, Continuous payment Cashflows.

Unit III

The investment and risk characteristics of the different types of assets available for investment purposes, Variable interest rates, Investment and risk characteristics of various types of assets such as bonds, shares, options and derivatives.

Unit IV

Forwards, Future, Call options, Put options, Put-call parity and swap, Structure of interest rates, Simple stochastic models for investment returns.

Contents (Practical):

1. Accumulation of a single investment at a constant rate of interest under the operation of simple and compound interests
2. Finding present value of a future payment, discounting a single investment under the operation of simple discount at a constant rate of discount.
3. Examples of annuities certain, Level payment annuities, Level payment perpetuities, Repayment mode (monthly),
4. Examples of Non-level payment annuities and perpetuities: Geometric, Increasing and Decreasing,
5. Examples of Continuous payment cash-flows.
6. Using Variable interest rates, study of Investment and risk characteristics of various types of assets such as bonds, shares, options and derivatives.
7. Problems on Forwards, Future, Call options, Put options, Put-call parity and swap.
8. Applications of simple stochastic models for investment returns.

References:

1. Dixit, S. P., Modi C.S. and Joshi R.V. (2000). Mathematical Basis of Life Assurance. Insurance Institute of India, Bombay.
2. Donald, D.W.A. (2016). Compound Interest & Annuities Certain. Cambridge University Press.
3. Hull, J. C. (2017). Derivatives Options & Futures, Tenth Edition, Pearson Education.
4. Joshi, M. S. (2008). The Concepts and Practice of Mathematical Finance. Cambridge University Press.
5. Kellison, S. G. (2008) The Theory of Interest. 3rd edition. McGraw-Hill/Irwin.
6. Ross, S. (2011). An Elementary Introduction to Mathematical Finance. Cambridge University Press.

ST-DSE-6: Clinical Trials and Epidemiology**Credits 6 (Theory: 4 + Practical: 2)****Learning Outcomes:**

The course is of applied nature and will provide the students about

- (a) the basic idea of various terminologies in epidemiology, clinical trial experiments involving different phases etc.,
- (b) the ethics, principles and conduct of clinical trial experiments with an overall view of Phase I-IV trials,
- (c) various data management and data collection systems for a good clinical trial practice,
- (d) population pharmacokinetics and pharmacodynamics models applicable in clinical trials,
- (e) various clinical trial designs commonly employed in practice,
- (f) design and monitoring of Phase III trials with various stopping rule, the inferential aspects including classical methods of interval estimation and hypotheses testing etc.,
- (g) design and analysis of epidemiological studies including case-control and cohort study designs,

- (h) sufficient practical knowledge by means of laboratory assignments on different types of real life data sets.

Contents (Theory):

Unit I

Introduction to clinical trials: the need and ethics of clinical trials, bias and random error in clinical studies, conduct of clinical trials, overview of Phase I – IV trials, multicenter trials. Data management: data definitions, case report forms, database design, data collection systems for good clinical practice. Bioavailability, bioequivalence, area under curve, rate of absorption of drug, rate of elimination, maximum concentration of drug and time of maximum concentration of drug. Pharmacokinetics and pharmacodynamics.

Unit II

Design of clinical trials: parallel group versus cross-over designs; cross-sectional versus longitudinal designs, wash-out period, control arms, single arms, active control, placebo; observational trials: prospective, retrospective; case-control, matching, cohort studies, quantitative methods in screening.

Unit III

Design and monitoring of phase III trials with sequential stopping, design of bioequivalence trials. Inference for 2X2 cross over design, classical methods of interval hypothesis testing for bioequivalence. Introduction to Meta-analysis of clinical trials.

Introduction to modern epidemiology, principles of epidemiologic investigation, surveillance and disease monitoring in populations.

Unit IV

Epidemiologic measures: organizing and presenting epidemiologic data, measure disease frequency, measures of effect association, causation and causal inference.

Design and analysis of epidemiologic studies: types of studies, case-control studies, cohort studies, quantitative methods in screening.

Contents (Practical):

1. Data preparation, cleaning and obtaining summary measures from clinical data.
2. Computation of odds ratio, Attributable Risk, risk ratio and relative risk.
3. Computation of bioavailability, bioequivalence, area under curve, rate of absorption of drug, rate of elimination, maximum concentration of drug and time of maximum concentration of drug.

4. Calculation of test of significance of cross-over effects, treatments effects and sequence of treatment effects.
5. Systematic representation of epidemiological data using statistical package.
6. Computation of disease frequency.
7. Calculation of effect association of disease using various measures.
8. Calculation of causation and causal inference for given epidemiological data.

References:

1. Chow, S.C. and Liu, J.P. (2004). Design and Analysis of Clinical Trials. 2nd Edition. Marcel Dekker.
2. Chow, S.C. and Liu, J.P. (2009). Design and Analysis of Bioavailability and Bioequivalence. 3rd Edition. CRC Press.
3. Fleiss, J.L. (1989). The Design and Analysis of Clinical Experiments. Wiley and Sons.
4. Friedman, L.M., Furburg, C. and Demets, D.L. (1998). Fundamentals of Clinical Trials. Springer.
5. Jekel, J.F., Elmore, J.G. and Katz, D.L. (1996). Epidemiology, Biostatistics and Preventive Medicine. WB Saunders Co.
6. Jennison, C. and Turnbull, B.W. (1999). Group Sequential Methods with Applications to Clinical Trials. CRC Press.
7. Marubeni, E. and Valsecchi, M.G. (1994). Analyzing Survival Data from Clinical Trials and Observational Studies. Wiley and Sons.
8. McNeil, D. (1996). Epidemiological Research Methods, Wiley and Sons.
9. Piantadosi, S. (1997). Clinical Trials: A Methodologic Perspective. Wiley and Sons.
10. Rothman, K.J. and Greenland, S. (1988). Modern Epidemiology. Lippincott-Raven.
11. Selvin, S. (1996). Statistical Analysis of Epidemiologic Data. Oxford University Press.

ST-DSE-7: Geostatistics**Credits 6 (Theory: 4 + Practical: 2)****Learning Outcomes:**

This course will provide the students an idea of

- (a) basic geostatistical concepts including the topics on spatial data analysis,
- (b) drawing important inferences on geostatistical and spatial data problems,
- (c) various graphical techniques relevant to geostatistical and spatial data analysis

- (d) variogram models and their analysis, maximum likelihood and Bayesian method on such aspects
- (e) kriging and its importance in geostatistical and spatial data problems
- (f) real data applications through laboratory assignments on the relevant inferential aspects including estimation and testing.

Contents (Theory):

Unit I

Introduction to Geostatistical Data: Spatial data, areal data, point referred data, natural resource data etc. Autocorrelation and its effect on statistical inference, spatial continuity and differentiability, random field in spatial domain.

Unit II

Spatial description: Contour Maps, Symbol Maps, Indicator Maps, Moving Window Statistics, Proportional Effect, Spatial Continuity, h-Scatterplots, Correlation Functions, Covariance Functions, Cross h-Scatterplots.

Unit III

Variogram and its mathematical properties, variogram model and its fitting using least squares with predefined weights, generalized least squares, Maximum likelihood and Bayesian method. Statistical tests for validation of the models. Simple Applications of the variogram. Variography in the presence of a drift. Estimation of variance of the sample variogram.

Unit IV

Kriging: Kriging with known mean and unknown mean. Estimation of a spatial average, lognormal kriging, Trans-Gaussian, Disjunctive block kriging, Indicator kriging and constraint kriging.

Contents (Practical):

1. Importing geostatistical data in R, important measures from geostatistical data, contour map, h-scatterplot, etc. from geostatistical data.
2. Plotting variogram for spatial continuity of a single variable and the cross-variogram for describing the cross-continuity between two variables.

3. Variogram model and its fitting using least squares with predefined weights, least squares and maximum likelihood estimates.
4. Fitting variogram model using generalized least square method and Bayesian method.
5. Calculation of variography in the presence of a drift.
6. Estimation variance of the sample variogram.
7. Estimation of a spatial average, lognormal kriging, Trans-Gaussian with known and unknown mean.
8. Estimation of disjunctive block kriging, Indicator kriging and constraint kriging with known and unknown mean.

References:

1. Bivand, R.S., Pebesmaand, E. and Virgilio Gómez-Rubio. (2013). Applied Spatial Data Analysis with R. Springer.
2. Chilès, J.P. and Delfiner, P. (2012). Geostatistics: Modeling Spatial Uncertainty. John Wiley & Sons.
3. Diggle, P. and Paulo Ribeiro, P.J. (2007). Model-Based Geostatistics. Springer.
4. Isaaks, E. H. and Srivastava, R. M. (1989). An Introduction to Applied Geostatistics. Oxford University Press.
5. Schabenberger, O. and Gotway, C.A. (2017). Statistical Methods for Spatial Data Analysis. CRC Press.

ST-DSE-8: Econometrics

Credits 6 (Theory: 4 + Practical: 2)

Learning Outcomes:

The course on econometrics will primarily focus on the use of statistical modelling and the relevant analyses to economic data problems. The students will get a thorough idea of

- (a) various important econometric models and relevant model building concepts in econometrics
- (b) general linear models and estimation of inherent model parameters
- (c) multicollinearity, its detection and consequences and related inferential aspects

- (d) some advanced concepts of generalised least squares estimation, autocorrelation, its consequences, detection and strategy for reducing autocorrelation,
- (e) heteroscedasticity and its inherent concepts including its consequences,
- (f) some inferential aspects on heteroscedasticity,
- (g) practical aspects and real data illustration of the related problems.

Contents (Theory):

Unit I

Introduction: Objective behind building econometric models, nature of econometrics, model building, role of econometrics, structural and reduced forms. General linear model (GLM). Estimation under linear restrictions.

Unit II

Multicollinearity: Introduction and concepts, detection of multicollinearity, consequences, tests and solutions of multicollinearity, specification error.

Unit III

Generalized least squares estimation, Aitken estimators. Autocorrelation: concept, consequences of autocorrelated disturbances, detection and solution of autocorrelation.

Unit IV

Heteroscedastic disturbances: Concepts and efficiency of Aitken estimator with OLS estimator under heteroscedasticity. Consequences of heteroscedasticity. Tests and solutions of heteroscedasticity. Autoregressive and Lag models, Dummy variables, Qualitative data.

Contents (Practicals):

1. Problems based on estimation of General linear model.
2. Testing of parameters of General linear model.
3. Forecasting of General linear model.
4. Problems concerning specification errors.
5. Problems related to consequences of Multicollinearity.
6. Diagnostics of Multicollinearity.
7. Problems related to consequences of Autocorrelation (AR(I)).
8. Diagnostics of Autocorrelation.
9. Estimation of problems of General linear model under Autocorrelation.

10. Problems related to consequences Heteroscedasticity.
11. Diagnostics of Heteroscedasticity.
12. Estimation of problems of General linear model under Heteroscedastic distance terms.
13. Problems related to General linear model under (Aitken Estimation).
14. Problems on Autoregressive and Lag models.

References:

1. Gujarati, D. and Sangeetha, S. (2007). Basic Econometrics, 4th Edition, McGraw Hill Companies.
2. Johnston, J. (1972). Econometric Methods, 2nd Edition, McGraw Hill International.
3. Koutsoyiannis, A. (2004). Theory of Econometrics, 2nd Edition, Palgrave Macmillan Limited.
4. Maddala, G.S. and Lahiri, K. (2009): Introduction to Econometrics, 4th Edition, John Wiley & Sons.

ST-DSE-9: Stochastic Processes and Queuing Theory**Credits 6 (Theory: 4 + Practical: 2)****Learning Outcomes:**

The students will get acquainted with some important and useful concepts on

- (a) probability distributions, generating functions including bivariate generating functions etc.,
- (b) Markov chains including the notion of transition probability matrix,
- (c) various other stochastic processes such as Poisson process, birth and death processes, queuing process and Gambler ruin problems,
- (d) application of these processes in real life problems,
- (e) practical aspects relevant to above problems based on the considered topics.

Contents (Theory):**Unit I**

Probability Distributions: Generating functions, Bivariate probability generating function. Stochastic Process: Introduction, Stationary Process.

Unit II

Markov Chains: Definition of Markov Chain, transition probability matrix, order of Markov chain, Markov chain as graphs, higher transition probabilities. Generalization of independent Bernoulli trials, classification of states and chains, stability of Markov system, graph theoretic approach.

Unit III

Poisson Process: postulates of Poisson process, properties of Poisson process, inter-arrival time, pure birth process, Yule Furry process, birth and death process, pure death process.

Unit IV

Queuing System: General concept, steady state distribution, queuing model, M/M/1 with finite and infinite system capacity, waiting time distribution (without proof). Gambler's Ruin Problem: Classical ruin problem, expected duration of the game.

Contents (Practical):

1. Calculation of transition probability matrix.
2. Identification of characteristics of reducible and irreducible chains.
3. Identification of types of classes.
4. Identification of ergodic transition probability matrix.
5. Stationarity of Markov chain and graphical representation of Markov chain.
6. Computation of probabilities in case of generalizations of independent Bernoulli trials.
7. Calculation of probabilities for given birth and death rates and vice versa.
8. Calculation of probabilities for Birth and Death Process.
9. Calculation of probabilities for Yule Furry Process.
10. Computation of inter-arrival time for a Poisson process.
11. Calculation of Probability and parameters for (M/M/1) model and change in behavior of queue as N tends to infinity.
12. Calculation of generating function and expected duration for different amounts of stake.
13. Computation of probabilities and expected duration between players.

References:

1. Basu, A.K. (2005). Introduction to Stochastic Processes. Narosa Publishing.

2. Bhat, B.R. (2000). Stochastic Models: Analysis and Applications. New Age International Publishers.
3. Cox, D.R. and Smith, W.L. (1991). Queues. CRC Press.
4. Feller, W. (1968). Introduction to probability Theory and Its Applications, Vol I, 3rd Edition. Wiley International.
5. Medhi, J. (2009). Stochastic Processes. New Age International Publishers.
6. Ross, S. M. (1996). Stochastic Processes. John Wiley.
7. Ross, S.M. (2014). Introduction to Probability Models. 11th Eds. Elsevier publisher.
8. Taha, H. (1995). Operations Research: An Introduction. Prentice- Hall India.
9. Taylor, H.M. and Karlin, S. (1998). An Introduction to Stochastic Modeling. Academic Press.

ST-DSE-10: Project

Students will opt for a compulsory industrial Project in Semester VI. A copy of rules and regulations regarding completion and submission of the project work by a student and assessment of the project work to make available in the Department of Statistics in each university. Students should use advanced statistical tools in their project and submit the dissertation at the end of the semester. There will be subsequent presentations and seminars by the students along with project supervisor, internal subject expert and Head of the Department. The grades on the presentation and evaluation of the project will be given by the subject expert and project supervisor allotted to the student. The project has to be completed within a semester. At the end of this project, students can analyze and interpret and take appropriate decisions in solving real life problems using statistical tools in the present situations.

Learning Outcomes:

At the end of this project, students will be in a position to

- (a) analyze and interpret and take appropriate decisions in solving real life problems using statistical tools.
- (b) use different Statistical packages for graphical interface, data analysis and interpretation,
- (c) write a systematic Statistical project report.

Syllabi of Generic Electives/Interdisciplinary

Courses ST-GE-1: Introduction to Statistics

Credits 6 (Theory: 4 + Practical: 2)

Learning Outcomes:

This course is designed for students other than statistics discipline and can be opted as choice based credit system (CBCS). This course will make the students conversant with

- (a) various techniques used in summarization, presentation and analysis of different types of Statistical data,
- (b) various summary measures of central tendency, dispersion, moments, skewness and kurtosis.
- (c) simple and rank correlation, Partial and Multiple correlation coefficients.
- (d) fitting of linear and quadratic regressions using principle of least squares.
- (e) measures of association for 2×2 and $r \times s$ contingency tables.
- (f) have knowledge on theoretical as well as practical approach.

Contents (Theory):

Unit I

Introduction: Definition and scope of Statistics, concepts of statistical population and sample. Scales of measurement -nominal, ordinal, interval and ratio. Variables and attributes, Diagrammatical Representation of Data, Summarization of Data: Frequency Distribution and Graphical Presentation.

Unit II

Measures of Central Tendency: mathematical and positional. Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation, moments, measures of skewness and kurtosis.

Unit III

Bivariate data: Definition, scatter diagram, simple correlation, rank correlation. Trivariate Data: Partial and Multiple correlation coefficients.

Unit IV

Fitting of linear and quadratic regression using principle of least squares. Theory of attributes and consistency of data, independence and association of attributes, measures of association and contingency for 2×2 and $r \times s$ contingency tables.

Contents (Practical):

1. Identification of scales of measurement, variables and attributes.
2. Diagrammatical representation of data, Summarization of data: Frequency Distribution and graphical Presentation.
3. Measures of central tendency: mathematical and positional.
4. Measures of dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation, moments, measures of skewness and kurtosis.
5. Scatter diagram, simple correlation, rank correlation.
6. Partial and Multiple correlation coefficients.
7. Fitting of linear and quadratic regression using principle of least squares.
8. Measures of association for 2×2 and $r \times s$ contingency tables.

References:

1. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2013). Fundamental of Statistics, Vol I, World Press, Kolkata.
2. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2011). Fundamental of Statistics, Vol II, World Press, Kolkata.
3. Hanagal, D. D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.
4. Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
5. Mood, A.M. Graybill, F.A. and Boes, D.C. (2011). Introduction to the Theory of Statistics, 3rd Edn., (Indian Edition), Tata McGraw-Hill Pub. Co. Ltd.

ST-GE-2: Introduction to Probability Theory

Credits 6 (Theory: 4 + Practical: 2)

This course is designed for students other than statistics discipline and can be opted as choice based credit system (CBCS). This course will lay the foundation to probability theory and Statistical modeling of outcomes of real life random experiments through various Statistical distributions.

Learning Outcomes:

The students will get to know about

- (a) writing of sample space, events and algebra of events and finding Probability of events,
- (b) conditional Probability and applications of Theorem of total probability and Bayes' theorem,
- (c) discrete and continuous Random Variables, Probability mass function (p.m.f.) and Probability density function (p.d.f.), Cumulative distribution function (c.d.f.)
- (d) Expectation, variance, moments and moment generating function.
- (e) problem solving pertaining to binomial, Poisson, geometric, negative binomial, hyper geometric, uniform, normal, exponential, beta, gamma distributions.
- (f) fitting of Binomial, Poisson and Normal distributions
- (g) Chebyshev's inequality, Convergence in probability, Weak law of large numbers, Convergence in distribution, De-Moivre Laplace and Lindeberg-Levy Central Limit Theorems (C.L.T.),
- (h) various aspects as outlined above through practical assignments.

Contents (Theory):**Unit I**

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

Unit II

Random Variables: Discrete and continuous random variables, Probability mass function (p.m.f.), Probability density function (p.d.f.), Cumulative distribution function (c.d.f.) Illustrations of random variables and their properties. Expectation, variance, moments and moment generating function.

Unit III

Standard probability distributions: Binomial, Poisson, geometric, negative binomial, hyper geometric, uniform, normal, exponential, beta, gamma and their applications. Fitting of Binomial, Poisson and Normal Distributions

Unit IV

Chebyshev's inequality, Convergence in probability, Weak law of large numbers, Convergence in Distribution, De-Moivre Laplace and Lindeberg-Levy Central Limit Theorems (C.L.T.).

Contents (Practical):

1. Writing sample space, events and algebra of events.
2. Finding Probability of events.
3. Computing Conditional Probability, Use of laws of addition and multiplication, Problems on independent events, theorem of total probability and applications of Bayes' theorem.
4. Identifying Discrete and continuous Random Variables, writing Probability mass function (p.m.f.) and Probability density function (p.d.f.), Finding Cumulative distribution function (c.d.f.)
5. Finding Expectation, variance, moments and moment generating function.
6. Problem solving pertaining to binomial, Poisson, geometric, negative binomial, hyper geometric, uniform, normal, exponential, beta, gamma distributions.
7. Fitting of Binomial, Poisson and Normal distributions
8. Problems on Chebyshev's inequality, Convergence in probability, Weak law of large numbers, Convergence in distribution, De-Moivre Laplace and Lindeberg-Levy Central Limit Theorems (C.L.T.).

References:

1. Hanagal, D. D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.
2. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009). Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi.
3. Meyer, P.L. (1970). Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi.
4. Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
5. Rohatgi, V. K. and Saleh A.K.M.E. (2008). An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.

ST-GE-3: Introduction to Statistical Inference

Credits 6 (Theory: 4 + Practical: 2)

This course is designed for students other than statistics discipline and can be opted as choice based credit system (CBCS).

Learning Outcomes:

The students will get an exposure to

- (a) techniques of estimation and testing of hypotheses for mean, variance, proportions, correlation coefficient, association and goodness of fit,
- (b) confidence intervals for the parameters of a normal distribution (one and two-sample problems),
- (c) Test of significance for correlation coefficient, Fisher's z –transformation,
- (d) Tests of proportions, tests of association and goodness-of-fit using Chi-square test, Yates' correction,
- (e) analysis of variance technique for one and two way classifications,
- (f) analysis of commonly used experimental designs such as CRD, RCBD etc.,
- (g) non-parametric tests such as Sign test for median and symmetry, Wilcoxon two-sample test,
- (h) practical applications through laboratory assignments.

Contents (Theory):

Unit I

Estimation of population means, confidence intervals for the parameters of a normal distribution (one and two-sample problems).

The basic idea of significance test, Null and alternative hypothesis. Type I & Type II errors, level of significance, concept of p-value. Tests of hypotheses for the parameters of a normal distribution (one and two-sample problems).

Unit II

Test of significance for correlation coefficient. Fisher's z –transformation,

Categorical data: Tests of proportions, tests of association and goodness-of-fit using Chi-square test, Yates' correction.

Unit III

Analysis of variance, one-way and two-way classifications. Brief exposure of three basic principles of design of experiments, treatment, plot and block. Analysis of completely randomized design, randomized complete block design.

Unit IV

Basic idea of non-parametric tests, sign test for median, sign test for symmetry, Wilcoxon two-sample test.

Contents (Practical):

1. Estimation of population means,
2. Finding confidence intervals for the parameters of a normal distribution (one and two-sample problems).
3. Tests of hypotheses for the parameters of a normal distribution (one and two-sample problems).
4. Test of significance for correlation coefficient, Fisher's z -transformation.
5. Tests of proportions, tests of association and goodness-of-fit using Chi-square test, Yates' correction.
6. Analysis of variance (one-way and two-way classifications).
7. Sign test for median and sign test for symmetry.
8. Wilcoxon two-sample test.

References:

1. Chap, T.L. and Eberly, L.E. (2016). Introductory Biostatistics. Wiley.
2. Daniel Wayne W. and Cross, C.L. (2013). Bio-statistics: A foundation for Analysis in the Health Sciences. John Wiley.
3. Das, M.N. and Giri, N.C. (1986). Design and analysis of experiment, Second Edition. John Wiley.
4. Dunn, O. J. and Clarke V.A. (2009). Basic Statistics: A Primer for the Biomedical Sciences, Fourth Edition. John Wiley.
5. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2013). Fundamental of Statistics, Vol I. World Press, Kolkata.
6. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2011). Fundamental of Statistics, Vol II. World Press, Kolkata.
7. Hanagal, D. D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.

8. Pagano, M. and Gauvreau, K. (2018). Principles of Biostatistics, Second Edition. Chapman and Hall/CRC.

ST-GE-4: Introduction to Applied Statistics

Credits 6 (Theory: 4 + Practical: 2)

Learning Outcomes:

This course is designed for students other than statistics discipline and can be opted as choice based credit system (CBCS).

The course will expose the students to

- (a) time series, index numbers, quality control and demographic methods,
- (b) different methods of measurements in time series
- (c) computation of different types of index numbers, consumer price index number,
- (d) quality control charts for variables and attributes helpful in industry for maintaining quality,
- (e) measures of fertility and mortality useful for helping the govt. to make decisions,
- (f) practical applications of the various concepts outlined above.

Contents (Theory):

Unit I

Economic Time Series: Component of time series, Decomposition of time series-Additive and multiplicative models with their merits and demerits, Illustrations of time series. Measurement of trend by method of free-hand curve. Method of semi-average and method of least squares (linear, quadratic and modified exponential) Measurement of seasonal variations by method of ratio to trend.

Unit II

Index numbers: Definition, Criteria for a good index number, different types of index numbers. Construction of index number of prices and quantities, consumer price index number. Uses and limitation of index numbers.

Unit III

Statistical Quality Control: Importance of statistical methods in industrial research and practice. Determination of tolerance limits. Causes of variations in quality: chance and assignable causes. General theory of control charts, process & product control, control charts for variables: \bar{x} and R-charts. Control charts for attributes: p and c charts

Unit IV

Demographic Methods: Introduction to measurement of population, rates and ratios of vital events. Measurement of mortality: Crude Death Rate (CDR), Standardised Death Rate (SDR) (w.r.t. age and sex). Measurement of fertility and reproduction: Crude Birth Rate (CBR), Gross Fertility Rate (GFR) and Total fertility rate (TFR).

Life (mortality) tables: definition of its main functions and uses, Measurement of population growth: Gross Reproduction Rate (GRR), Net Reproduction Rate (NRR).

Contents (Practical):

1. Measurement of trend by method of free-hand curve. Method of semi-average and method of least squares (linear, quadratic and modified exponential) Measurement of seasonal variations by method of ratio to trend.
2. Computation of different types of index numbers, consumer price index number.
3. X and R charts
4. p and c charts
5. Computation of Crude Death Rate (CDR), Standardised Death Rate (SDR) (w.r.t. Age and sex).
6. Computation of Crude Birth Rate (CBR), Gross Fertility Rate (GFR) and Total fertility rate (TFR).
7. Completion of a life table by computing values of different functions.
8. Computation of Gross Reproduction Rate (GRR), Net Reproduction Rate (NRR).

References:

1. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2011). Fundamental of Statistics, Vol II. World Press, Kolkata.
2. Gupta, S.C. and Kapoor, V.K. (2008). Fundamentals of Applied Statistics. 4th Edition (Reprint), Sultan Chand & Sons.
3. Montgomery, D.C. (2009). Introduction to Statistical Quality Control. 6th Edition, Wiley India Pvt. Ltd.
4. Mukhopadhyaya, P. (1999). Applied Statistics. New Central Book Agency, Calcutta.

ST-GE-5: Introduction to Operations Research

Credits 6 (Theory: 4 + Practical: 2)

Learning Outcomes:

The students shall get exposed to

- (a) graphical and simplex method of solving linear programming problem (LPP) for finding degenerate, unbounded, alternate and infeasible solutions,
- (b) use of duality to solve a LPP,
- (c) obtaining solution of a transportation problem by North West corner method, Matrix Minima method, Vogel's method,
- (d) Hungarian Method for solving assignment problems,
- (e) game theory, minimax-maximin rules, graphical solution of $m \times n$ or $2 \times n$ rectangular game and mixed strategy,
- (f) networking problem using shortest route.

Contents (Theory):

Unit I

Introduction to Operations Research (OR), phases of OR, model building, various types of OR problems. Linear Programming Problem, Mathematical formulation of the LPP, graphical solutions of a LPP.

Unit II

Optimum solution to a LPP: Simplex method, concept of artificial variables and Charne's big M-technique. Graphically identifying special cases of LPP. Concept of duality in LPP.

Unit III

Transportation Problem: Initial solution by north west corner rule, least cost method and Vogel's approximation method (VAM), MODI's method to find the optimal solution. Assignment problem: Hungarian method to find optimal assignment.

Unit IV

Game theory: Rectangular game, minimax-maximin principle, solution to rectangular game using graphical method, dominance property to reduce the game matrix and solution to rectangular game with mixed strategy. Networking: Shortest route problem.

Contents (Practical):

1. Mathematical formulation of LPP and solving the problem using graphical method.
2. Simplex technique to solve LPP and reading dual solution from the optimal table.
3. Charne's Big M-method involving artificial variables.
4. Identifying special cases: Degenerate solution, Unbounded solution, Alternate solution and Infeasible solution by Graphical method and interpretation.
5. Allocation problem using Transportation model.
6. Allocation problem using Assignment model.
7. Networking: Shortest route problem.
8. Problems based on game matrix: $m \times 2$ / $2 \times n$ Rectangular and Mixed strategies.

References:

1. Ravindran, A, Phillips, D.T. and Solberg, J. J. (2005). Operations Research- Principles and Practice. John Wiley & Sons.
2. Swarup, K., Gupta, P.K. and Mohan, M. (2007). Operations Research, 13th Edition. Sultan Chand and Sons.
3. Taha, H. A. (2007). Operations Research: An Introduction, 8th Edition. Prentice Hall of India.

Syllabi of Skill Enhancement Courses (SEC)

ST-SEC-1: Computational Techniques and R Programming

Credits 4 (Theory: 3 + Practical: 1)

Learning Outcomes:

The students will get acquainted with

- (a) various basic concepts related to computer architecture and its organization, various peripheral devices,
- (b) languages: machine language, assembly language and high level languages,
- (c) ideas on operating systems, linker, loader and compiler etc.,
- (d) R programming with some basic notions for developing their own simple programs and visualizing graphics in R.

Contents (Theory):

Unit I

Computer basics: Introduction and brief history of evolution of computers, Classification of computers: special purpose and general purpose; analog, digital and hybrid; Super, main-frame etc.

Unit II

Organization of general purpose digital computers: CPU, main memory and peripherals.

Mass storage devices and other I/O devices.

Computer languages: Machine code language (machine language), assembly language and high level languages. Software: Operating systems, linker, loader, compiler, interpreter and assembler.

Unit III

Computer programming: Algorithm and flow-chart. Storage of information: concepts of records and files. File organization: sequential, relative and indexed.

Unit IV

Programming with R: Introduction to R, Data types in R (numeric, logical, character, complex etc.), R objects: vector, matrix, array, list, data frame, factor, and time series. Arithmetic, logical and relational operators, explicit and implicit looping, functions and functional

programming in R, Lexical scoping rules in R, benefits of Lexical scoping, other scoping rules, debugging facility in R. Few important mathematical, statistical and graphical functions in R.

Contents (Practical):

Practicals are based on the topics of the theory mentioned above.

References:

1. Chambers, J. (2008). Software for Data Analysis: Programming with R, Springer.
2. Crawley, M.J. (2017). The R Book, John Wiley & Sons.
3. Eckhouse, R.H. and Morris, L.R. (1975). Minicomputer Systems Organization, Programming and Applications, Prentice-Hall.
4. Matloff, N. (2011). The Art of R Programming, No Starch Press, Inc.
5. Peter N. (1986). Inside the IBM PC, Prentice-Hall Press.

ST-SEC-2: Computational Statistics and Database Management System

Credits 4 (Theory: 3 + Practical: 1)

Learning Outcomes:

The students shall be exposed to

- (a) various computational algorithms relevant to statisticians as support system,
- (b) codes preferably using R language,
- (c) Linear congruential and mid-square methods for uniform generator,
- (d) Inverse transform method for simulating various probability distributions and stochastic models,
- (e) data base management system with special emphasis on significance of topic to the statisticians,
- (f) Entity relationship, Relational, Hierarchical and Network Models,
- (g) practical assignments on above mentioned topics.

Contents (Theory):

Unit I

Graphical methods with applications: histogram, Quantile based plot (boxplot and Q-Q plot), scatter diagram, time series plot, autocorrelation plot.

Computation of the normal integral, Student's t-integral, non-central t integral, Gamma, Beta integral for positive real numbers. Computation of incomplete beta and incomplete gamma integral, computation of Bessel function and modified Bessel function.

Unit II

Generation of uniform random numbers (mid-square method and linear congruential generator).

Simulation of probability distributions and stochastic models (Inverse transformation method only). Applications of simulation techniques.

Unit III

Introduction. Purpose of database systems. Database abstraction. Data models. Instances and schemes. Data independence. Data definition and data manipulation languages. Database manager, Administrators and users.

Unit IV

Entity relationship model, Entities and entity sets. Relationships and relationship sets, Attributes, Mapping constraints, Keys, Entity relationship diagram. Reducing E-R diagrams to tables. Aggregation, Design of an E-R database scheme.

Relational models. Structure of relational database. Distributed database. Relational algebra. Relational commercial languages. SQL. Relational database design. Query languages and query processing. Crash recovery. Concurrency control. Hierarchical model. Network model.

Contents (Practical):

Practicals are based on the topics of the theory mentioned above.

References:

1. Date, C.J. (1981). Introduction to Database Systems, Addison-Wesley.
2. Kennedy W. J. & Gentle J. E. (1980). Statistical Computing, Marcel Dekker.
3. Korth, H.F. and Silberschatz, A. (2010). Database System Concepts, McGraw-Hill.
4. Ross, S.M. (2012). Simulation. Academic Press.

5. William H. P. and William T. V. (1992). Numerical Recipes in C: The Art of Scientific Computing, Cambridge University Press.

ST-SEC-3 Statistical Techniques for Research Methods

Credits 4 (Theory: 3 + Practical: 1)

Learning Outcomes:

Statistical Techniques provide scientific approaches to develop the domain of human knowledge largely through empirical studies. The course will enable the students to

- (a) understand basic concepts and aspects related to research, data collection, analyses and interpretation,
- (b) Prepare and finalize research report on some real life situations.

Contents (Theory):

Unit I

Introduction: Meaning, objectives and motivation in research, types of research, research approach, significance of research. Research problems: definition, selection and necessity of research problems.

Unit II

Survey methodology and data collection, inference and error in surveys, the target populations, sampling frames and coverage error, methods of data collection, non-response, questions and answers in surveys.

Unit III

Processing, Data Analysis and Interpretation: Review of various techniques for data analysis covered in core statistics papers, techniques of interpretation, precaution in interpretation.

Unit IV

Develop a questionnaire, collect survey data pertaining to a research problem (such as gender discriminations in private v/s government sector, unemployment rates, removal of subsidy, impact on service class v/s unorganized sectors), interpret the results and draw inferences.

Contents (Practical):

Students should submit a research report based on empirical study on some real life situation. The student will personally collect, analyze, interpret the data and prepare a report under the supervision of a faculty.

References:

1. Kothari, C.R. (2009): Research Methodology: Methods and Techniques, 2nd Revised Edition reprint, New Age International Publishers.
2. Kumar, R (2011): Research Methodology: A Step - by - Step Guide for Beginners, SAGE Publications.

7. Teaching Learning Processes

The teaching learning processes play the most important role in achieving the desired aims and objectives of the undergraduate programs in Statistics as elaborated in detail in the Learning Based Curriculum Framework (LOCF). Statistics is the science which deals with data collection, analysis and interpretation of numerical data. While such ideas and concepts originate in the minds of the genius, anywhere and anytime in the universe, their verifications and confirmations have to be done in the data analysis. To achieve this goal, the appropriate training of young individuals to become competent statisticians in future have to be accomplished. For this purpose, a very good undergraduate program in Statistics is the first step. We should therefore have an excellent teaching-learning procedural protocol for all the colleges, universities and other Higher Education Institutions (HEI). To be specific, it is desirable to have:

- Necessary and sufficient infrastructural facilities for the class rooms, laboratories and libraries equipped with adequate modern and modular furniture and other requirements.
- Modern and updated computer laboratory equipment are needed for the undergraduate programme.
- Recent reference and text books for the libraries are to be updated.
- Sufficient infrastructure for ICT and other facilities needed for technology-enabled learning like computer facilities, PCs, laptops, Wi-Fi and internet facilities with all the necessary software.
- Sufficient number of teachers in permanent position to do all the class room teaching

and perform and supervise the computer laboratory experiments to be done by the students.

- All the teachers should be qualified as per the UGC norms and should have good communication skills.
- Sufficient number of technical and other support staff to run the laboratories, libraries, equipment and maintain the infrastructural facilities like buildings, electricity, sanitation, cleanliness etc.
- Teachers should make use of all the approaches for an efficient teaching-learning process i.e.
 - (i) Class room teachings with lectures using traditional as well as electronic boards,
 - (ii) Use of smart class rooms for simulation and demonstration for conveying the difficult concepts and tools of Statistics in class room teaching and laboratories,
 - (iii) Tutorials must be an integral part of all the theory and laboratory courses. Theory courses should have 1-2 tutorials every week depending upon the nature of the course,
 - (iv) Teaching should be complimented with student's seminar to be organized very frequently,
 - (v) Guest lectures and seminars/workshops should be arranged by eminent teachers to be invited by the concerned college/university/HEI,
 - (vi) Open-ended project work should be given to all students individually or in group to 2-3 students depending upon the nature of the course,
 - (vii) Internship of duration varying from one week anytime in the semester and/or 2-6 weeks during semester break and summer breaks should be arranged by the college/universities/HEI for the students to visit other colleges/universities/HEI and industrial organizations in the vicinity. If needed, financial assistance may also be provided for such arrangements to be made for their internship in industries.
 - (viii) Special attempts should be made by the institution to develop problem-solving skills and design of Statistics projects for demonstration at the UG level. For this purpose, a mentor system may be evolved where 3-4 students may be assigned to each faculty member,
 - (ix) Teaching load should be managed such that the teacher has enough time to interact with the students to encourage an interactive/participative learning.

8. Assessment Methods

In the undergraduate education of Statistics leading to the B. Sc. Statistics (Honors) degree, the assessment and evaluation methods focus on testing the conceptual understanding of the basic ideas, development of mathematical skills and experimental techniques retention and ability to apply the knowledge acquired to explain with analysis and reason what has been learnt and to solve new problems and communicate the results and findings effectively. Since the learning objectives are defined clearly for each course in detail, it is easier to design methods to monitor the progress in achieving the learning objectives during the course and test the level of achievement at the end of the course.

- The courses offered in the undergraduate Statistics are the first courses at the college/university level, the priority should be given to Formative Assessment for monitoring the progress towards achieving the Learning Objectives while keeping its weightages lower than Summative Assessments. This is to assure that the students know their strengths and weaknesses periodically through the results of Formative Assessments and make amends for the gaps in their knowledge without affecting their final grades in any significant way. In this context it is suggested that 25-30% weightage be given Formative Assessments in case of theory components while 30-40% weightage be given to the Laboratory/Field work/Projects/Case Study/Dissertation components of the various courses. Moreover, use of more than one method of Assessment in each course is highly recommended.
- Some of the methods suggested for Theory Component with regard to Formative Assessment are i) Regular Tutorial assignments ii) seminar presentations iii) Performance in group discussions iv) Problem based longer assignments (other than tutorials) v) True/False Tests vi) Multiple Choice Tests vii) Short Answer Tests viii) viva-voce tests ix) Any other innovative tests in the context of the course.
- In the case of substantive Summative Assessment for the theory papers, can be a combination of the following i) Mid -Semester test ii) Seminar Report iii) Individual /Team Project report iv) Oral Presentations of Seminar/Projects v) Viva -Voce Examination on the above reports.
- End Semester closed book examination in the pattern of a) Multiple Choice b) Short Answer c) Long Answer.

- End Semester Open Book Examination in the form of a) Peer review by a group of experts by written and oral examinations, b) Any other innovative method depending upon the nature of the course.
- B. Laboratory Experiments / Field work / Projects / Case Study / Dissertation can be assessed for Formative Assessment through i) Regular evaluation of Lab. experiments regarding written report of each experiment and Viva-Voce on each experiment, ii) Mid semester examination.
- At the end, the main purpose of Statistics teaching should be to impart objective knowledge to students in concrete, comprehensive and effective way. Here, effectiveness implies gaining knowledge and skill which can be applied to solve practical problems as well as attaining capability of logical thinking and imagination which are conducive to new knowledge and new discoveries. The student shall embrace the curriculum in a way which would incite imagination and imbibe a spirit of enquiry in them, so that in future they will opt for further investigations or research. Needless to say, there should be a continuous evaluation system for the students. This will enable the teachers not only to ascertain the overall progress of learning by the students, but also to identify the students who are slow learner and for whom special care should be taken. An appropriate grading system is the 'relative grading system' can also be envisaged for certain papers, introducing a competitive element among the students. All in all, the teacher should act as a facilitator and guide and not as a guardian of curriculum.
- HEIs can design their own ways and methods to quantify the assessment and evaluation based on the above methods. It would then be converted to the letter grades by the procedure described by the template given by the UGC.
- Once the letter grade for a course is obtained for a course, it should be done for all the courses offered by the student. Once the letter grades for all the courses are accumulated, then a CGPA should be calculated by quantifying the letter grades as described by the template provided by the UGC.

9. Key Words

- Actuarial Statistics
 - Analytical Reasoning
 - Communication Skills
 - Course Learning Outcomes
 - Critical Thinking
 - Design of Experiments
 - Disciplinary Knowledge
 - Econometrics
 - Financial Statistics
 - Geo-Statistics
 - Graduate outcomes
 - Nonparametric inference
 - Optimization Techniques
 - Probability Theory
 - Probability Distributions
 - Problem Solving
 - Program Learning Outcomes
 - Qualification Descriptors
 - Queuing Theory
 - Regression analysis
 - Reliability
 - Research-related Skills
 - Sampling Techniques
 - Scientific Reasoning
 - Skill Development
 - Statistical Inference
 - Statistical Quality Control
 - Survival Analysis
 - Testing of Hypotheses
 - Time Series Analysis.
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