Institute of Statistical Research and Training
University of Dhaka

Syllabus

B.S. Honors Program in Applied Statistics
Session : 2016–2017

www.isrt.ac.bd/syllabus

B.S. Honors Program in Applied Statistics

The B.S. honors course in Applied Statistics is an integrated four-year program. The program includes courses of both theoretical and applied nature, but more emphasis is given on the applications of the statistical techniques to real life situations. The course is so designed that after successful completion, the graduates are equipped to work efficiently and completely in government and non-government organizations, research organizations, service departments and other related fields.

The examination consists of four parts, one at the end of each academic year. Each student has to take a total of 140 credits over four academic years. These include 107 credits of theoretical courses, 22 credits of computing courses and 8 credits of oral. For theoretical courses, 23 credits will be from courses of Mathematics, Economics and Computer Science. Thirty percent marks of the theoretical courses and forty percent marks of the computing courses will be allotted for in-course examination.

The marks allocation for theoretical courses will be as follows:

Attendance	:	05
In-course exam	:	25
Final exam	:	70

The marks allocation for computing courses will be as follows:

Attendance/assignment	:	10
In-course exam	:	30
Final exam	:	60

There will be two in-course examinations for each of the theoretical and computing courses.

A student with high academic attainment in S.S.C. and H.S.C. or equivalent levels with Mathematics as a subject of study is eligible for admission. The regulations for admission of the students and the examinations will be same as those of the B.S. honors courses in the Faculty of Science unless otherwise stated.

Distribution of courses, credits, marks and detailed syllabus are as follows:

Courses for the First Year

Course ID	Course Title	Credit
AST 101	Elements of Applied Statistics	4
AST 102	Elements of Probability	4
AST 103	Programming with C/C++	3
AST 104	Basic Mathematics	3
AST 105	Calculus	4
AST 106	Principles of Economics	4
AST 107	Linear Algebra	3
AST 130	Statistical Computing I	2
AST 131	Statistical Computing II	2
AST 140	Oral I	2
Total		31

Courses for the Second Year

Course ID	Course Title	Credit
AST 201	Sampling Distributions and Simulation	4
AST 202	Actuarial Statistics	3
AST 203	Statistical Inference I	3
AST 204	Design and Analysis of Experiments I	3
AST 205	Introduction to Demography	3
AST 206	Sampling Methods I	4
AST 207	Mathematical Methods	3
AST 230	Statistical computing III: R and Matlab	2
AST 231	Statistical Computing IV	2
AST 232	Statistical Computing V	2
AST 240	Oral II	2
Total		31

Courses for the THIRD Year

Course ID	Course Title	Credit
AST 301	Design and Analysis of Experiment II	4
AST 302	Sampling Methods II	3
AST 303	Linear Regression Analysis	4
AST 304	Epidemiology	3
AST 305	Population Studies	3
AST 306	Statistical Inference II	3
AST 307	Multivariate Statistics I	3
AST 308	Industrial Statistics and Operations Research	4
AST 309	Mathematical Analysis	3
AST 330	Statistical computing VI: SPSS, Stata and SAS	2
AST 331	Statistical Computing VII	2
AST 332	Statistical Computing VIII	2
AST 340	Oral III	2
Total		38

Courses for the FOURTH Year

Course ID	Course Title	Credit
AST 401	Advanced Probability and Stochastic Processes	4
AST 402	Statistical Inference III	3
AST 403	Multivariate Statistics II	4
AST 404	Econometric Methods	4
AST 405	Lifetime Data Analysis	4
AST 406	Research Methodology and Social Statistics	4
AST 407	Analysis of Time Series	3
AST 408	Generalized Linear Models	3
AST 430	Statistical Computing IX	2
AST 431	Statistical Computing X	2
AST 432	Statistical Computing XI	2
AST 440	Oral IV	2
AST 450	B.S. Project	3
Total		40

Detailed Syllabus - First Year

AST 101: Elements of Applied Statistics — Credit 4

Introduction to statistics: meaning of statistics; scopes and limitations; concepts of descriptive and inferential statistics; basic concepts: data, sources of data - primary and secondary data; population, sample, parameter, statistic; variables and types of variable: qualitative and quantitative discrete, continuous; scales of measurements; classification of variable by scales of measurements.

Organization and presentation of data: graphical presentation for qualitative and quantitative data; use of excel software; sorting data, grouping qualitative and quantitative data: construction of frequency distribution and relative frequency distribution; graphical presentation of frequency distribution- histogram, frequency polygon, ogive.

Concept of distribution: location, scale (spread) and shape, illustration with stem and leaf diagram; use of excel software; descriptive measures of data; measures of location; measures of dispersion; moments and their interrelationship; measures of skewness and kurtosis; three and five number summary; box-plot and modified box-plot; use of excel software.

Description of bivariate data: bivariate frequency distribution; graphical presentation of bivariate data; contingency table; concept of association between two variables; percentage table and interpretation of cell frequencies; measures of association for nominal and ordinal variables; measures of association for interval or ratio variables; correlation; relationship between two variables: simple linear regression; use of excel software; basic issues in inferential statistics.

Text Books

1. Newbold P (2004). Statistics for business and economics, *third edition.* Prentice-Hall.
2. Weiss N (2007). Introductory statistics, *seventh edition.* Addison Wesley.

AST 102: Elements of Probability — Credit 4

Combinatorial analysis: basic principles of counting, permutations, combinations; axioms of probability: sample space and events, axioms of probability, sample spaces

having equally likely outcomes, probability as a measure of belief; conditional probability and independence: conditional probabilities, Bayes formula, independent events.

Random variables: introduction, discrete random variables, expectation, expectation of a function of a random variable, variance, Bernoulli and binomial random variables, Poisson random variable, other discrete random variables (geometric, negative binomial, hypergeometric); expected value of a sums of random variables; properties of cumulative distribution function; continuous random variables: expectation and variance of continuous random variable, normal random variable, normal approximation to binomial distribution, exponential random variables.

Jointly distributed random variables: joint distribution functions, independent random variables, sums of independent random variables, conditional distributions (discrete and continuous cases); properties of expectation: expectation of sums of random variables, covariance, variance of sums, correlations, conditional expectation, moment generating functions, probability generating function.

Text Books

1. Ross SM (2009). A first course in probability, *eighth edition*. Prentice-Hall.

AST 103: Programming with **C/C++** | **Credit 3**

Introduction to programming: algorithm, flowchart, code (program); levels of programming: machine level, assembly level and high level language; execution of code: translator, compiler, interpreter, assembler; steps of execution: compilation, link, run.

An overview of C: the origins of the C language, compilers versus interpreters; variables, constants, operators, and expressions: data types, declaration of variables, assignment statements, constants, operators, expressions; program control statements: C statements, conditional statements, loop statements, labels; functions: the return statement, function arguments, arguments to main(), returning pointers, pointers to functions; arrays: single-dimension arrays, passing single dimension arrays to functions, two- and multi-dimensional arrays, arrays and pointers, allocated arrays, array initialization;

Applications of C programming in data analysis: frequency distributions, data summary, e.g. mean, median, maximum, minimum, matrix operations, calculation of different rates, fitting simple linear regression, sorting a vector, optimizing nonlinear functions using Newton-Raphson iterative procedure, numerical integration and differentiation.

Introduction to Python.

Text Books

1. Dietel PJ and Deitel HM (2010). C how to program, *seventh edition.* Pearson.
2. Thomas H (2016). An Introduction to Statistics with Python: With Applications in the Life Sciences. Springer.

AST 104: Basic Mathematics | **Credit 3**

Basic Algebra

Theory of numbers: unique factorization theorem; congruencies; Euler's phi-function; inequalities: order properties of real numbers; Weierstrass', Chebysev's and Cauchy's inequalities; inequalities involving means; complex numbers: field properties; geometric representation of complex numbers; operations of complex numbers; summation of algebraic and trigonometric finite series; theory of equations: relations between roots and coefficients; symmetric functions of roots; Descartes rule of signs; rational roots; Newton's method.

Beta and gamma function and their properties; incomplete beta and gamma function; Dirichlet's theorem; Liouville's extension of Dirichlet's theorem.

Differential Equations

Formulation of simple applied problems in terms of differential equations; equations of the first order and their solutions; singular solutions; geometric applications; linear equations with constant coefficients; method of undermined coefficients; variation of parameters and inverse differential operators; simple cases of linear equations with variable coefficients.

Text Books

1. Ayres F (1995). Theory and problems of modern algebra. McGraw-Hill.
2. Ross SL (1980). Introduction to ordinary differential equations, *fourth edition.* Wiley.

AST 105: Calculus | **Credit 4**

Part A: Differential Calculus

Real numbers and function; limit and continuity of functions of one variable; derivative of a function of one variable; geometric interpretation of the derivative; differentiation formulas; the chain rule; implicit differentiation; derivatives from parametric

equations; higher order derivatives; Leibnitiz's theorem; increasing and decreasing functions; extrema of functions; concavity; Rolle's mean value theorems; applications of the theory of extrema, velocity and acceleration related rates; differentials.

Indeterminate forms; infinite limits; tangent; normal; curvature; asymptote; curve tracing; areas; functions of several variables; limit and continuity; partial derivatives; chain rule; total differentials; Jacobian extrema.

Part B: Integral Calculus

The anti derivatives (indefinite integral); elementary integration formulas; integration by parts; integration by substitution; integration of rational functions; the definite integral; fundamental theorem of calculus; properties of definite integrals; evaluation of definite integrals; simple reduction formulas.

Arc lengths; volumes and surfaces of solids of revolution; Lagrange multiplier; multiple integrals; evaluation of double and triple integrals by iteration; area, volume and mass by double and triple integration.

Text Books

1. Anton H (1995). Calculus with analytic geometry, *fifth edition*. Wiley.
2. Stewart J (2006). Calculus: early transcendentals (Stewart's calculus series).

AST 106: Principles of Economics | **Credit 4**

Definition and scope of economics; theory of demand and supply; demand schedule; supply schedule; equilibrium of demand and supply; elasticity of demand and supply: measurement of elasticity; price elasticity of demand and supply.

Demand and consumer behavior; utility theory; equi-marginal principle; indifference curve analysis: consumers surplus; individual and market demand; derivation of demand curve; theory of production: production function; total, average and marginal product; law of diminishing returns; factors of production; pricing of factors of production; division of labor; localization of industries; returns to scale; law of variable proportion; isoquants; Cob-Douglas and CES production function; theory of cost; fixed and variable cost; total and marginal costs; least cost rule; opportunity cost.

Market structure: perfect and imperfect competition; pricing under monopoly, oligopoly and monopolistic competition; short-run and long-run equilibrium analysis; income and wealth: factor incomes vs. personal incomes, role of government, wealth; fundamentals of wage determination, the supply of labor, determinants of supply, empirical findings, wage differentials; basic concepts of interest and capital, prices and rentals on investments, rates of return and interest rates, present value of assets, real vs. nominal interest rates.

Key concepts of macroeconomics: objectives and instruments of macroeconomics; measuring economic success, tools of macroeconomic policy; real vs. nominal GDP, "Deflating" GDP by a price index; consumption, investment, NDP, GNP, price indexes and inflation; consumption and saving: consumption function, saving function; investment: determinants of investment, revenues; theories of economic growth: four wheels of growth, human and natural resources, capital; theories of economic growth: classical dynamics of Smith and Malthus, neoclassical growth model.

Index number: characteristics, problems in the construction, classification; methods: unweighted, weighted: Laspeyre's, Paasche's, Dorbish and Bowley's, Fisher's, Marshall and Edgeworth's, Kelly's and the chain index numbers; test of accuracy, base shifting, splicing, deflating of index numbers; application of consumer price index number.

Text Books

1. Samuelson PA and Nordhaus WD (2009). Economics, *nineteenth edition.* McGraw Hill.
2. Mankiw NG (2015). Principles of Economics, *seventh edition.* Cengage Learning.
3. Dowling ET (2011). Introduction to Mathematical Economics, *third edition.* McGraw-Hill Education.
4. Newbold P, Carlson W and Thorne B (2012). Statistics for Business and Economics, *eighth edition.* Pearson

---

AST 107: Linear Algebra | **Credit 3**

Matrices, vectors and their operations: Basic definitions and different types of matrices, matrix operations (addition, multiplication), trace of a matrix, determinant and adjoint of a square matrix, properties of determinants, inverse of matrix, properties of inverse, Kronecker product and related Operations.

System of linear equations: Gaussian elimination, Gauss-Jordan elimination, homogeneous linear systems, null spaces and the general solution of linear systems, rank and linear systems, generalized inverse of a matrix, generalized inverses and linear systems.

Vector spaces and subspaces: Vector addition and scalar multiplication, linear spaces and subspaces, intersection and sum of subspaces, linear independence and dependence, basis and dimension, inner product, norms and orthogonality, Orthogonal projections, Gram-Schmidt orthogonalization.

Eigenvalues and eigenvectors: Eigenvalue equation, characteristic polynomial and its roots, Eigenspaces and multiplicities, Diagonalizable matrices, Computation of eigenvalues and eigenvectors.

Singular value and Jordan decompositions: Singular value decomposition, SVD and linear systems, Computing the SVD, Jordan canonical form.

Quadratic forms: Matrices in quadratic forms, Positive and nonnegative definite matrices, Congruence and Sylvester's Law of Inertia, Nonnegative definite matrices and minors, Some inequalities related to quadratic forms, Simultaneous diagonalization and the generalized eigenvalue problem.

Text Books

1. Banarjee S and Roy A (2014). Linear algebra and matrix analysis for statistics. Chapman and Hall.
2. Anton H and Rorres C (2005). Elementary linear algebra, *fourth edition*. Wiley.

AST 130: Statistical Computing I — **Credit 2**

Computing problems related to Elements of Applied Statistics.

AST 131: Statistical Computing II — **Credit 2**

Computing problems related to Programming with C/C++ and Linear Algebra.

AST 140: Oral I — **Credit 2**

Detailed Syllabus - Second Year

AST 201: Sampling Distributions and Simulation

Credit 4

Generating function techniques: moment generating function, cumulant generating function, probability generating function, characteristic function; finding distributions of functions of random variables: change of variable technique, distribution function technique and moment-generating function technique; probability integral transformation; statistic and sampling distribution; law of large numbers; central limit theorem; exact distribution of sample mean; chi-square distribution and its properties; F-distribution and its properties; t-distribution and its properties; non-central chi-square, F and t distributions: definition and derivation; concept of order statistics, distributions of single order statistics and joint distribution of two or more order statistics.

Brief review of some discrete distributions; continuous probability distribution and their properties: uniform, normal, exponential, gamma, beta, log-normal, Cauchy; definition of truncated distribution; definition of compound and mixture distribution; family of distribution: Pearsonian distribution.

Concepts of simulation and its uses in statistics; random number generations: congruential generators, seeding; random variate generations: inversion method (direct method), rejection method (indirect method); simulating discrete random variables; simulating normal random variables: rejection with exponential envelope, Box-Muller algorithm; Monte-Carlo integration: hit-and-miss method, improved Monte-Carlo integration; variance reduction: antithetic sampling, importance sampling, control variates.

Text Books

1. Robinson E (1985). Probability Theory and Applications. Springer Science & Business Media.
2. Wadsworth GP and Bryan JG (1960). Introduction to Probability and Random Variables. McGraw-Hill.
3. Zehna PW (1970). Probability distributions and statistics. Allyn and Bacon.
4. Jones O, Maillardet R and Robinson A (2009). Introduction to scientific programming and simulation using R. Chapman & Hall/CRC.

AST 202: Actuarial Statistics | **Credit 3**

The meaning of actuarial science; role of insurance in the economy; role of an actuary.

Fundamentals of theory of interest: definition of simple interest and compound interest and their comparisons; accumulated value factors and present value factors; effective and nominal rates of interest and their interrelationship; effective and nominal rates of discount; relation between interest and discount; equations of value and use of the time diagram in solutions of problems in interest; problems involving unknown length of investment and unknown rate of interest; annuity; different types of annuities certain; present and accumulated values of immediate annuity and annuity due; present value of deferred annuities and variable annuities; capital redemption policies; amortization schedules and sinking funds.

Actuarial mathematics: discrete life annuity and its applications; present values of different life annuities; life assurance; present values of various life assurances in terms of commutation functions; related problems; premiums; different types of premiums; net premiums; office premiums; prospective policy values.

The basic deterministic model: cash flows; an analogy with currencies; discount functions; calculating the discount function; interest and discount rates; constant interest; values and actuarial equivalence; regular pattern cash flows; balances and reserves; basic concepts; relationship between balances and reserves.

Stochastic interest-rate models: stochastic interest-rate models I; basic model for one stochastic interest rate; independent interest rates; stochastic interest-rate models II; dependent annual interest rates; modelling the force of interest; what can one do with these models.

Text Books

1. Kellison SG (1991). The theory of interest, *second edition.* McGraw-Hill/Irwin.
2. Promislow SD (2011). Fundamentals of actuarial mathematics, *second edition.* John Wiley & Sons.

AST 203: Statistical Inference I | **Credit 3**

Basic Concepts: Fundamental ideas of statistical inference; parametric and non-parametric inference; estimators, statistics, parameters; sampling distributions and uses in inference; point estimation, interval estimation and test of hypothesis; theory and reality.

Point estimation of parameters and fitting of probability distributions: descriptive statistics; exploratory data analysis; least squares estimation; moments based estimation; maximum likelihood estimation; uses of graphical tools for assessing goodness of fit; asymptotic distributions of maximum likelihood estimators.

Interval estimation: methods for constructing confidence interval - pivotal quantity method, Wald- type method, likelihood ratio based method; confidence intervals for means; confidence intervals for the difference of two means; confidence intervals for proportions; interpretation of confidence interval.

Testing hypotheses and assessing goodness of fit: heuristics of hypothesis testing; errors in hypothesis testing-statistical significance and power; exact tests and approximate tests; tests about one population mean, test about the equality of two population (independent and paired) means; test about the equality of more than two population means; test about proportions; likelihood ratio test; statistical tests applied to categorical data- Fisher's exact test, chi-square test of homogeneity and independence; chi-square goodness of fit tests.

Text Books

1. Hogg RV, Tanis EA and Zimmerman DL (2015). Probability and statistical inference, *ninth edition.* Pearson.
2. Hogg RV, McKean J and Craig AT (2010). Introduction to mathematical statistics, *seventh edition.* Pearson.

AST 204: Design and Analysis of Experiments I

Credit 3

Introduction to design of experiments: strategy of experimentation; some typical examples of experimental design; basic principles; guidelines for designing experiments.

Experiments with a single factor: the analysis of variance; analysis of fixed effects model; estimation of model parameters; unbalanced data; model adequacy checking; regression model, comparisons among treatment means, graphical comparisons of means, contrasts, orthogonal contrasts, multiple testing, Scheffe's method, comparing pairs of treatment means, comparing treatment means with a control; Determining sample size; operating characteristic curve, specifying standard deviation increase, confidence interval estimation method; discovering dispersion effects; regression approach to analysis of variance; least squares estimation of the model parameters, general regression significance test; nonparametric methods in analysis of variance; the Kruskal-Wallis test.

Randomized blocks, Latin squares, and related designs: the randomized complete block designs (RCBD); statistical analysis of RCBD, model adequacy checking; es-

timating model parameters; Latin square design; Graeco-Latin square design; balanced incomplete block design (BIBD); statistical analysis of BIBD; least squares estimation of BIBD; recovery of intra-block information in the BIBD.

Text Books

1. Montgomery DC (2001). Design and analysis of experiments, *fifth edition*. Wiley.

AST 205: Introduction to Demography | **Credit 3**

Basic concept of demography; role and importance of demographic/population studies; sources of demographic data: census, vital registration system, sample surveys, population registers and other sources especially in Bangladesh.

Errors in demographic data: types of errors and methods of testing the accuracy of demographic data; quality checking and adjustment of population data; post enumeration check (PEC) and detection of errors and deficiencies in data and the needed adjustments and corrections.

Fertility: basic measures of fertility; crude birth rate, age specific fertility rates (ASFR), general fertility rate (GFR), total fertility rate (TFR), gross reproduction rate (GRR) and net reproduction rate (NRR), child-woman ratio; concept of fecundity and its relationship with fertility.

Demographic theory: transition theory and the present situation in Bangladesh; Malthus' theory and its criticism. mortality: basic measures of mortality: crude death rate (CDR), age specific death rates (ASDR), infant mortality rate, child mortality rate, neo-natal mortality rate; standardized death rate its need and use; direct and indirect standardization of rates; commonly used ratios: sex ratio, child-woman ratio, dependency ratio, density of population.

Fertility and mortality in Bangladesh since 1951: reduction in fertility and mortality in Bangladesh in recent years; role of socio-economic development on fertility and mortality.

Nuptiality: marriage, types of marriage, age of marriage, age at marriage and its effect on fertility, celibacy, widowhood, divorce and separation, their effect on fertility and population growth.

Migration: definition, internal and international migration; sources of migration data; factors affecting both internal and international migration, laws of migration; impact of migration on origin and destination, its effect on population growth, age and sex structure, labor supply, employment and unemployment, wage levels, and other socio-economic effects; migration of Bangladeshis abroad and its impact on overall economic development of the country.

Text Books

1. Siegel SJ and Swanson DA (2004). The methods and materials of demography, *second edition*. Emerald.
2. Shryock S and others (1975). The methods and materials of demography, volume I and II. U.S. Department of Commerce Publication.

AST 206: Sampling Methods I | **Credit 4**

Role of sampling theory; requirements of a good sample design; units; population; sampling units; sampling frame and uses of sample survey; random or probability sampling and non-random or purposive sampling; bias; precision and accuracy of estimates; different types of errors associated with sampling and complete enumeration.

Simple random sampling: drawing of samples; with and without replacement sampling-estimates, standard errors and confidence intervals; simple random sampling for proportion and ratio estimate, standard error and confidence interval; determination of sample size for specified precision.

Systematic sampling: use, limitation, estimates, bias, standard error and efficiency; comparison with simple random sampling; systematic sampling for populations with linear trend; methods for dealing with population with linear trend or periodic variation.

Stratification: reasons for stratification; formulation and number of strata; stratified random sampling estimates, standard error and confidence interval; allocation of samples to strata equal allocation, proportional allocation, Neyman allocation and optimum allocation; stratified sampling for proportions; post stratification and quota sampling.

Use of supplementary information: ratio estimation with examples, estimated bias, mean squared error, approximate variance; conditions for unbiased ratio estimation; unbiased ratio-type estimates; necessity and limitation of ratio estimates; ratio estimates in stratified random sampling; comparison of the combined and separate estimates; product and difference estimation.

Regression estimation: examples, assumptions, properties and limitations; bias and approximate variance; estimate of the variance; regression estimates in stratified sampling combined and separate estimates; comparative merits and demerits of ratio and regression estimates.

Cluster sampling: reasons, formation of clusters, size of clusters; simple cluster sampling with equal and unequal sized clusters estimates, bias, standard error and

efficiency; comparison with simple random sampling and systematic sampling; determination of optimum cluster size.

Stratified cluster sampling: advantages, estimates, bias, standard error and efficiency; comparison with simple random sampling, systematic sampling and usual stratified random sampling.

Text Books

1. Cochran WG (1977). Sampling techniques, *third edition.* Wiley.
2. Lohr SL (1998). Sampling: design and analysis. Duxbury.

AST 207: Mathematical Methods | **Credit 3**

Interpolation and inverse interpolation: uses of Newton's forward and backward interpolation formula; Lagrange's formula; numerical integration: Simpson's rule; Weddle's rule; trapezoidal rule; Gauss's quadratic formulae and proper examples from the applications to econometric, meteorology and biomedicine; Euler's formula of summation and quadrature.

Solution of numerical algebraic and transcendental equations; equations in one unknown; finding approximate values of the roots; finding roots by repeated application of location theorem; method of interpolation or of false position; solution by repeated plotting on a large scale; Newton-Raphson method; Newton-Raphson method for simultaneous equations.

Fourier series: periodic function; Fourier series process of determining the Fourier coefficients; Dirichlet conditions; odd and even functions; half range Fourier sine or cosine series; Parseval's identity; differentiation and integration of Fourier series.

Laplace transform: introduction; definition of integral transformation; definition of Laplace transform; Laplace transform of some elementary functions; sufficient conditions for the existence of Laplace transform; some important properties of Laplace transform; initial and final value theorem; Laplace transforms of some special functions.

Inverse Laplace transform: definition of inverse Laplace transform; Lerch's theorem; some important properties of the inverse Laplace transform; partial function decompositions; definition of the convolution; convolution theorem; Heaviside's expansion formula; evaluation of integrals; application of Laplace transform.

Introduction to Taylor's and Laurent series.

Text Books

1. Burden RJ and Faires JD (2010). Numerical analysis, *ninth edition*. Brooks Cole.
2. Kreyszig E (2011). Advanced Engineering Mathematics, *tenth edition*. Wiley.
3. Jeffrey A (2001). Advanced Engineering Mathematics. Academic Press.

AST 230: Statistical Computing III: **R** and **Matlab** | **Credit 2**

Introduction to R

History and overview of R programming language, R objects, matrices, lists, data frames, reading and writing data files, subsetting R objects, vectorized operations, control structures, functions (both in-built and custom), different loop functions, simulation, calling C function from R.

Exploratory data analysis: managing data frames with dplyr package, exploratory graphs, summary statistics, different plotting systems (base, ggplot2, lattice).

Introduction to Matlab/Octave

Introduction; basic features; command window; mathematical operations in command window; array operation; matrix operations; logical operations; script m-files; function m-files; data input and output; statistical graphics: common plots in statistics, three dimensional plot, color maps, mash, and surface plots.

Programming and exploratory data analysis with Matlab/Octave.

Text Books

1. Peng RD (2015). R programming for data science. Leanpub.
2. Peng RD (2015). Exploratory data analysis with R. Leanpub.
3. Quarteroni A, Saleri F and Gervasio P (2010). Scientific computing with MATLAB and Octave, *third edition*. Springer.

AST 231: Statistical Computing IV | **Credit 2**

Simulation, fitting of probability distribution, point and interval estimation, test of hypothesis.

AST 232: Statistical Computing V | **Credit 2**

Design of experiments (completly randomized, randomized block, Latin square design), sampling methods (simple random, stratified, systematic and cluster sampling).

AST 240: Oral II | **Credit 2**

Detailed Syllabus – Third Year

AST 301: Design and Analysis of Experiments II

Credit 4

Introduction to factorial designs: basic definition and principles; advantage of factorials; two-factor factorial design; statistical analysis of fixed effects model, model adequacy checking, estimating model parameters, choice of sample size, assumption of no interaction in a two-factor model, one observation per cell; general factorial design; fitting response curve and surfaces; blocking in a factorial design.

2^k factorial design: introduction; 2^2 design; 2^3 design; general 2^k design; a single replicate in 2^k factorial design; blocking in a 2^k factorial design; confounding in 2^k factorial design; confounding in 2^k factorial design in two blocks; confounding in 2^k factorial design in four blocks; confounding in 2^k factorial design in 2^p blocks; partial confounding.

Two-level fractional factorial designs: one-half fraction of 2^k design; one-quarter fraction of 2^k design; general 2^{k-p} fractional factorial design; resolution III designs; resolution IV and V designs; three-level and mixed-level factorial and fractional factorial designs: 3^k factorial design, confounding in 3^k factorial design, fractional replication of 3^k factorial design, factorials with mixed levels.

Response surface methods: introduction to response surface methodology; method of steepest ascent; analysis of second-order response surface; experimental designs for fitting response surfaces; mixture experiments; robust designs.

Experiments with random factors: random effects model; two-factor factorial with random factors; two-factor mixed model; sample size determination with random effects; rules for expected mean squares; approximate F tests; approximate confidence intervals on variance components; modified large-sample method; maximum likelihood estimation of variance components.

Nested and split-plot designs: two-stage nested designs; statistical analysis, diagnostic checking, variance components; general m-staged nested design; designs with both nested and factorial factors; split-plot design; split-plot designs with more than two factors; split-split-plot design, strip-split-plot design.

Text Books

1. Dean AM and Voss AM (1999). Design and analysis of experiments. Springer.
2. Montgomery DC (2001). Design and analysis of experiments, *fifth edition*. Wiley.
3. Bailey R (2008). Design of comparative experiments. Cambridge.

AST 302: Sampling Methods II | **Credit 3**

Sampling of unequal clusters with unequal probability with and without replacement different selection methods: PPS selection, Brewer's, Durbin's, Samford's, PPS systematic, Raj's, Murthy's and Rao-Hartley-Cochran methods of selection; detailed study on the related formulae, estimates, variances, estimates of variances for these methods.

Two-stage sampling with equal and unequal sized clusters-estimates and standard errors; estimation for proportions; stratified two-stage sampling.

Multistage sampling: different two and three stage sampling schemes; the concept of self-weighting estimates; assumptions for self-weighting estimates; sampling schemes resulting in self-weighting estimates.

Method of variance estimation in complex surveys.

Multiphase sampling: reasons for adopting this technique; two-phase or double sampling; ratio and regression estimators for double sampling and respective standard errors; double sampling for stratification; repeated sampling; sampling from the same population on two occasion, more than two occasions; Interpenetrating subsampling. Concept of base line survey and panel survey.

Sampling and non-sampling errors: sources and types of non-sampling error; non-sampling bias; non-response error; control of non-response; techniques for adjustments of non-response; Role of design and model in sampling: design unbiasedness; model unbiasedness.

Special sampling schemes: inverse sampling; capture-recapture method; network sampling; snowball sampling; adaptive cluster sampling; rank set sampling.

Text Books

1. Cochran WG (1977). Sampling techniques, *third edition*. Wiley.
2. Lohr SL (1998). Sampling: design and analysis. Duxbury.

AST 303: Linear Regression Analysis | **Credit 4**

Measures of association for quantitative data: correlation and inference concerning correlation; regression and model building, motivating examples, uses of regression.

Simple linear regression model: model for $E(Y|x)$, least squares estimation, assumptions related to errors, maximum likelihood estimation (MLE) of model, sampling distribution of MLEs of the model parameters, inferences concerning the model parameters (confidence intervals and t-test), confidence interval estimate of the $E(Y|x)$ (confidence band).

Model accuracy and diagnostics: goodness of fit test (F-test, coefficient of determination, R^2); prediction and prediction interval for a new Y at specific x, residual analysis: definition, normal probability plot, plots of residuals versus fitted values, residuals versus x, other residual plots, statistical test on residuals; detection and treatment of outliers; concept of lack of fit and pure error, test for lack of fit, transformations as solution to problems with the model, weighted least squares.

Matrix representation of simple linear model, inference and prediction.

Multiple linear regression models: formulation of multiple regression models, estimation of the model parameters: least squares estimation, maximum likelihood estimation, sampling distributions of the MLEs, confidence interval and hypothesis testing for concerning model parameters; model accuracy and diagnostics: goodness of fit test (F test, R^2, adjusted R^2), prediction of a new observation; extra sum of squares principles and its application in testing general linear hypothesis, checking all assumptions concerning model and use of remedy measures when assumptions are not valid, detection and treatment of outliers, influential observations.

Polynomial regression model: introduction; polynomial models in one variable: basic principles, piecewise polynomial fitting; polynomial models in two or more variables; orthogonal polynomials.

Indicator variables: the general concept of indicator variable, use of the indicator variables in linear regression, models with only indicator variables, idea on regression models with an indicator response variable.

Variable selection and model building: the model building problem, consequences of model mis-specification, criteria for evaluating subset regression models, computational techniques for variable selection.

Validation of regression models: concept, cross validation.

Text Books

1. Weisberg S (2013). Applied Linear Regression, *fourth edition*. Wiley.
2. Montogomery CD and Peck E (1981). Introduction to linear regression analysis. Wiley and Sons.
3. Draper NR and Smith H (1999). Applied regression analysis, *third edition*. Wiley.

AST 304: Epidemiology | **Credit 3**

Introduction: disease processes, statistical approaches to epidemiological data, study design, binary outcome data, causality

Measures of disease occurrence: prevalence and incidence, disease rates, hazard function; review of simple random samples, probability, conditional probabilities, and independence of two events

Measures of disease-exposure association: relative risk, odds ratio, relative hazard, excess risk, attributable risk

Study designs: population-based studies, cohort studies, case-control studies, case-cohort studies; Assessing significance of 2×2 tables obtained from chohort designs, case-control designs

Estimation and inference for measures of assocaition: odds ratio, sampling distribution and confidence interval for odds ratio, relative risk, excess risk, attributable risk

Confounding and interaction: causal inference, counterfactuals, confounding variables, control of confounding variables by stratification, causal graphs, controllong confounding in causal graphs; Cochran-Mantel-Haenszel test, summary estimates and confidence intervals for odds ratio and relative risk after adjusting for confounding factors

Interaction: multiplicative and additive interaction, interaction and counterfactuals, test of consistency of association across strata, overall test of association, a test for trend in risk

Text Books

1. Jewell NP (2003). Statistics for Epidemiology. Chapman and Hall.
2. Kleinbaum DG, Kupper LL and Morgenstern H. (1982) Epidemiologic Research: Principles and Quantitative Methods. Wiley.

AST 305: Population Studies | **Credit 3**

Graduation of data: meaning and its need, techniques of graduation, graduation of age distribution; life table: its concept, structure and calculation, complete life table (life table by single year of age) and abridged life table, multiple decrement life tables, working life table, different life table functions and inter-relationships among them, use of life table, etc. Model life tables, Coale and Demeny regional model life tables.

Force of mortality: idea and definition calculation of life table with the help of force of mortality.

Population growth, techniques to measure it, doubling time concept in demography; population estimates and projections; different techniques of population projection- component method, arithmetic/linear method, geometric method, exponential method, matrix method, etc, need of population projections. Use of Lee-Carter model is population projections.

Stable and stationary population, their characteristics and uses; Lotka's characteristics equation, intrinsic birth and death rates, effect of uniform drop in force of mortality on the growth rate, effects of changes in fertility and mortality on the age distribution of population.

Population in Bangladesh: history of growth of population in Bangladesh; implications of the growth of population in Bangladesh; population policy in Bangladesh; level, trends and determinants in fertility, mortality and migration in Bangladesh; interrelationship between population and development; future prospects of population and population control in Bangladesh; aged and aging of population in Bangladesh.

Text Books

1. Shryock S and others (1975). The methods and materials of demography, volume I and II. U.S. Department of Commerce Publication.
2. Bogue DJ (1969). Principles of demography. Wiley.

AST 306: Statistical Inference II | **Credit 3**

Testing hypotheses: approaches to hypothesis testing- Neyman-Pearson approach, Fisher approach and Jeffreys' approach; error probabilities and the power function; the concept of a best test; best critical region; most powerful test via the Neyman-Pearson lemma; uniformly most powerful (UMP) test via the Neyman-Pearson Lemma; likelihood ratio property; UMP test via maximum likelihood ratio property; unbiased and UMP unbiased tests.

Principle of data reduction: Sufficiency- conditional distribution approach, Neyman factorization theorem; minimal sufficiency- Lehmann-Scheffe approach; information- one-parameter situation, multi-parameters Situation; ancillarity- location, scale, and location-scale families, its role in the recovery of information; completeness- complete sufficient statistics, Basu's theorem.

Likelihood based inference in exponential families: formulation; estimation- one parameter case and multi-parameter case; approximate normality of MLEs- estimating variance of MLEs; Wald tests and confidence interval; likelihood ratio test and confidence interval; inference about g(θ)- the delta method and applied to MLEs.

Criteria to compare estimators- unbiasedness, variance and mean squared error; best unbiased and linear unbiased estimators; improved unbiased estimator via sufficiency; the Rao-Blackwell theorem; uniformly minimum variance unbiased estimator(UMVUE); the Cramer-Rao inequality and UMVUE; the Lehmann-Scheffe theorems and UMVUE; a generalization of the Cramer-Rao inequality; evaluation of conditional expectations; unbiased estimation under incompleteness; does the Rao-Blackwell theorem lead to UMVUE? consistent estimators; comparison of estimators using decision theoretic approach - loss function and risk function; methods of evaluating interval estimators: size and coverage probability.

Text Books

1. Mukhopadhyay N (2000). Probability and statistical inference.
2. Rice J (2007). Mathematical statistics and data analysis.
3. Hogg RV, McKean J and Craig AT (2010). Introduction to Mathematical Statistics.

AST 307: Multivariate Statistics I | **Credit 3**

Preliminaries of multivariate analysis: applications of multivariate techniques; the organization of data; data display and pictorial representations; distance.

Random vectors and random sampling: some basic of matrix and vector algebra; positive definite matrices; a square-root matrix; random vectors and matrices; mean vectors and covariance matrices; matrix inequalities and maximization; the geometry of the sample; random sample and expected values of sample means and covariance matrix; generalized variance; sample mean, covariance, and correlation as matrix operations; sample values of linear combinations of variables.

The multivariate normal distribution: the multivariate normal density and its properties; sampling from a multivariate normal distribution and maximum likelihood estimation; sampling distribution and large sample behavior of sample mean vector and sample variance-covariance matrix; assessing the assumption of normality; detecting outliers and data cleaning; transformation to near normality.

Inferences about a mean vector: the plausibility of mean vector as a value for a normal population mean; Hotelling T^2 and likelihood ratio tests; confidence regions and simultaneous comparisons of component means; large sample inference about a population mean vector; inferences about mean vectors when some observations are missing; time dependence in multivariate data.

Comparisons of several multivariate means: paired comparisons and a repeated measures design; comparing mean vectors from two populations; comparison of several multivariate population means (one-way MANOVA); simultaneous confidence intervals for treatment effects; two-way multivariate analysis of variance; profiles analysis; repeated measures designs and growth curves;

Multivariate linear regression models: the classical linear regression model; least squares estimation; inferences about regression model; inferences from the estimated regression function; model checking; multivariate multiple regression; comparing two formulations of the regression model; multiple regression model with time dependent errors.

Text Books

1. Johnson RA and Wichern DW (1999). Applied multivariate statistical analysis, *fourth edition.* Prentice-Hall.
2. Srivastava MS (2002). Methods of multivariate statistics. Wiley.

AST 308: Industrial Statistics and Operations Research

Credit 4

Industrial Statistics

Fundamental concepts of industrial statistics and its purposes; industrial quality control: total quality control; statistical quality control; chance and assignable causes of variation; statistical process control.

Control chart: concept of control chart; statistical basis of the control chart; basic principles; choice of control limits; sample size and sampling frequency; rational subgroups; analysis of patterns on control charts; sensitizing rules for control charts; necessary steps for constructing control charts; types of control charts (control charts with standard given and control charts with no standard given); control charts for attributes: concepts of nonconformity; nonconforming unit; defect; defective unit; p-chart; d-chart; c-chart; u-chart; basic concepts of control charts for variables; statistical basis and interpretation of, R and S charts.

Cumulative sum and exponentially weighted moving average control charts: the cumulative sum control chart; basic principles; the tabular or algorithmic cusum for monitoring the process mean; recommendations for cusum design; the standardized

cusum; the exponentially weighted moving average control chart for monitoring the process mean; design of an EWMA control chart; robustness of the EWMA to non-normality; the moving average control chart.

Acceptance sampling: basic concepts of acceptance sampling; OC curve and its uses; types of OC curves; properties of OC curves. Single sampling plan: basic concepts of single sampling plan for attributes; construction of type A and type B OC curves under single sampling plan for attributes; specific points on the OC curve (AQL, LTPD); rectifying inspection; AOQ; AOQL; ATI; ASN; designing a single sampling plan; double sampling plan: basic concepts of double sampling plan; OC curve; ASN: AOQ; ATI; designing a double sampling plan; introduction to multiple sampling plan and sequential sampling analysis; acceptance sampling plan by variables: basic concepts of acceptance sampling plan; types of sampling plans; designing a variable sampling plan with a specified OC curve.

Operations Research

Nature and impact of OR approach; phases of OR; concept of linear programming problem (LPP); construction of LPP; solution of LPP: graphical and the simplex method; revised simplex method; big-M method, two phase method; concept of convergence, degeneracy and cycling; duality: dual primal relationship and formulation of dual problems; sensitivity analysis: introduction to sensitivity analysis; game theory: finite and infinite games; zero sum games; two person zero sum games; pay off matrix; maximum and minimum criterion of optimal solution of a game; dominance property; algebraic method for the solution of a game; equivalence of rectangular game matrix and linear programming; application in real life situation using MATLAB/Octave software.

Text Books

1. Montgomery DC (2004). Introduction to statistical quality control. Wiley.
2. Hillier FS, Lieberman GJ, Nag B and Basu P (2001). Introduction to operations research, *ninth edition*. McGraw-Hill.

AST 309: Mathematical Analysis | **Credit 3**

The real number system; axioms and completeness and its consequences; Dedekind cut, sets, compact sets; simple operation on them.

Sequence of functions of one and several variables; limit; continuity; continuous functions; uniform continuity; differentiation and integration; infinite series of constants and functions; convergence and divergence; power series: differentiation and integration of power series; Taylor expansion with remainder or in infinite series.

Metric and topological spaces; limit points; open and closed sets; interior and exterior points; boundary points; continuous mapping and Cauchy sequences.

Measure and integrals on abstract sets on real lines; Cramer measurability: fundamental definitions; auxiliary lemma; fundamental theorems; measurable functions; Lebesgue measure on a real line, plane; integrals; Riemann-Steiljes integrals.

Text Books

1. Rudin W (1976). Principles of mathematical analysis. McGraw-Hill.

AST 330: Statistical Computing VI: **SPSS, STATA, SAS**

Credit 2

SPSS

Introduction to SPSS; data entry, reading SPSS and other data sets, import; defining the variable with labels and value labels; working with date and time variable; data matching in both add cases and add variables; basic Data management: transformation of data using different (numeric, arithmetic, statistical, and logical) expressions, operations, and functions; different commands in SPSS: get, save, save outfile, split files, sort cases, compute, recode, if, select if, do if, end if, list, aggregate, sample selection, report; graphical presentation: simple bar graphs, line graphs, graphs for cumulating frequency and pie graphs; exploratory analysis: frequencies, descriptive statistics, multiple response, bivariate analysis - crosstabs.

Stata

Introduction to Stata: different windows and files, help file and searching for information; data entry, reading both stata and and other format of data file, combining Stata files; exploring data: example commands-browse, edit, list, sort, describe, assert, codebook; data management: creating a new data set specifying subsets of data with in and if qualifiers, generating and replacing variables, using functions based on egen command, converting numeric and string formats, creating new categorical and ordinal variables, reshaping or collapsing data, weighting observations, creating random data and random samples; graphs: example commands- histograms, scatterplots, line plots, connected-line plots, two-way plots, box plots, combining graphs; exploratory data analysis: summary statistics and tables: example commands: summarize, tabstat, table; frequency tables and two-way cross tabulations, multiple tables and multi-way cross tabulations, tables of means, medians and other summary statistics.

SAS

Introduction to SAS: overview of the SAS data step, syntax of SAS procedures, comment statements; reading different format of data set, infile options, creating and reading a permanent data sets, defining the variable: variable type, variable name, variable formats, variable labels, value labels, writing with large data sets, data set subsetting, concatenating, merging and updating; working with arrays; restructuring SAS data sets using arrays, describing data: describing data, more descriptive statistics, frequency distributions, bar graph and plotting data, creating summary data sets with proc means and proc univariate, outputting statistics other than means; analyzing categorical data: questionnaire design and analysis, adding variable and value labels, recoding data, two-way and multiple tables.

Text Books

1. Cody RP and Smith JK (2005). Applied statistics and the SAS programming language, 5^{th} *edition*. Prentice Hall.
2. Norusis MJ (1988). SPSS/PC for the IBM PC/XT/AT.
3. Hamilton LC (2006). Statistics with Stata, Thomson Brooks/Cole.

AST 331: Statistical Computing VII — **Credit 2**

Fitting simple and multiple regression, analysis of factorial experiment.

AST 332: Statistical Computing VIII — **Credit 2**

Inference, multivariate test and regression, LPP, life table, population pyramid.

AST 340: Oral III — **Credit 2**

Detailed Syllabus – Fourth Year

AST 401: Advanced Probability and Stochastic Processes

Credit 4

Modern probability: events as sets, field, sigma field, probability measure, Borel field and extension of probability measure, measure theoretic approach of random variables; probability space;

Convergence of random variables: modes of convergence: almost sure, rth mean, in probability, in distribution, their interrelationship; law of large numbers, strong and weak laws of large numbers, limiting distribution; central limit theorem; law of iterated logarithm; martingale.

Markov chains: introduction, Chapman-Kolmogorov equations, classification of states, limiting probabilities, gamblers ruin problem, mean time spent in transient states, branching processes, time reversible Markov chains, Markov chain Monte Carlo methods, Markov decision processes, hidden Markov chains.

Poisson process: exponential distribution, properties, convolutions of exponential random variables; counting processes, Poisson process, interarrival and waiting time distributions, further properties of Poisson processes, generalizations of the Poisson process, nonhomogeneous Poisson process, compound Poisson process, conditional or mixed Poisson processes.

Continuous-time Markov chains: introduction, continuous-time Markov chains, birth and death processes, transition probability function, limiting probabilities, time reversibility.

Introduction to Queueing theory: Classical M/M/1 queue, global and local balance, performance measures, Poisson arrivals see time averages (PASTA) property, M/M/1/S queueing systems, blocking probability, performance measures, multiserver systems M/M/m, performance measures, waiting time distribution of M/M/m, performance measures of M/M/m/m with finite customer population, Erlang loss systems.

Renewal theory and its applications : introduction, distribution of renewals, limit theorems and their applications, renewal reward processes, regenerative processes, semi–Markov processes, Markov renewal processes.

Text Books

1. Grimmett G and Stirzaker D (2001). Probability and random processes, *third edition*. Oxford.
2. Ross S (2010). Introduction to probability models, *tenth edition*. Elsevier.

AST 402: Statistical Inference III | **Credit 3**

Statistical inference: parametric, nonparametric and semiparametric inference.

Approximate and computationally intensive methods for statistical inference: the general problem of inference; likelihood functions; maximum likelihood estimation; optimization techniques- Newton type methods; EM algorithm- simple form, properties, uses in analysing missing data, fitting mixture models and latent variable model; restricted maximum likelihood (REML) method of estimation; Multi-stage maximization; Efficient maximization via profile likelihood; confidence interval and testing hypothesis in these complex cases; Bayesian method of inference: prior and posterior distribution, different types of prior, credible intervals and testing hypothesis; analytical approximations- asymptotic theory, Laplace approximation; numerical integral methods- Newton-Cotes type methods; Monte carlo methods; simulation methods- Markov chain Monte Carlo.

Resampling techniques: bootstrap- confidence intervals, test, parametric bootstrap, advantages and disadvantages of parametric bootstrap; jackknife- confidence interval, test and permutation test.

Nonparametric inference and robustness: introduction, inference concerning cumulative distribution function (cdf), quantiles and statistical functionals: empirical cdf, quantiles, estimating statistical functionals, influence functions, testing statistical hypothesis- one sample settings, two or more sample settings; tolerance limit; empirical density estimation- histograms, kernel, kernel density estimation.

Text Books

1. Casella G and Berger RL (2003). Statistical inference, *second edition*. Duxbery.
2. Millar RB (2011). Maximum likelihood estimation and inference: with examples in R, SAS and ADMB. Wiley.
3. Hogg RV, McKean J and Craig AT (2010). Introduction to Mathematical Statistics, *seventh edition*. Pearson.

AST 403: Multivariate Statistics II | **Credit 4**

Principal Components: population principal components, summarizing sample variations by principal components, graphing the principal components, large sample inference.

Factor Analysis: the orthogonal factor models, methods of estimation (maximum likelihood estimates and principal factor analysis), selection of loadings and factor (factor rotation, varimax rotation, quartimax rotation, oblimin rotations), factor scores, structural equations models.

Canonical Correlation Analysis: canonical variates and canonical correlations, sample canonical variates and sample canonical correlations, large sample inference.

Discrimination and Classification: separation and classification two populations, classification of two multivariate normal populations, evaluating classification functions, Fisher's discriminant function, classification with several populations, Fisher's method for discriminating several populations.

Clustering: similarity measures, hierarchical clustering methods, nonhierarchical clustering methods, Multidimensional scaling.

Text Books

1. Johnson RA and Wichern DW (1999). Applied multivariate statistical analysis, *fourth edition*. Prentice-Hall.
2. Srivastava MS (2002). Methods of multivariate statistics. Wiley.

AST 404: Econometric Methods | **Credit 4**

Econometric modeling, data and methodology; specification analysis and model building: bias caused by omission of relevant variables, pretest estimation, inclusion of irrelevant variables, model building; testing non-nested hypotheses, encompassing model, comprehensive approach - J test, Cox test; model selection criteria.

Models for panel data: fixed effects: testing significance of group effects, within- and between-groups estimators, fixed time and group effects, unbalanced panels and fixed effects; random effects: GLS, FGLS, testing for random effects, Hausmans specification test.

Simultaneous equations models: illustrative systems of equations, endogeneity and causality; problem of identification: rank and order conditions for identification; limited information estimation methods: OLS, estimation by instrumental variables (IV), Two-Stage Least Squares (2SLS), GMM Estimation, limited information maximum likelihood and the k class of estimators, 2SLS in nonlinear models;

system methods of estimation: Three-Stage Least Squares (3SLS). full-information maximum likelihood, GMM estimation, recursive systems and exactly identified equations; comparison of methods-Kleins Model I; specification tests; properties of dynamic models: dynamic models and their multipliers.

Models with lagged variables: lagged effects in a dynamic model, lag and difference operators; simple distributed lag models: finite distributed lag models, infinite lag model: geometric lag model; Autoregressive Distributed Lag (ARDL) models: estimation of the ARDL model, computation of the lag weights in the ARDL model, stability of a dynamic equation, forecasting; Vector Autoregressions (VAR): model forms, estimation, testing procedures, exogeneity, testing for Granger causality, impulse response functions, structural VARs, application: policy analysis with a VAR.

Limited dependent variable: truncated distributions, moments of truncated distributions, truncated regression model; censored data: censored normal distribution, censored regression (Tobit) model, estimation, issues in specification; censoring and truncation in models for counts, application: censoring in the Tobit and Poisson regression models.

Text Books

1. Greene WH (2011). Econometric analysis, *seventh edition*. Prentice Hall.
2. Gujarati DN (2010). Basic econometrics, *fifth edition*. McGraw-Hill.
3. Wooldridge JM (2010). Introductory econometrics: A Modern Approach, *fifth edition*. Cengage Learning.

AST 405: Lifetime Data Analysis | **Credit 4**

Basic concepts and models: lifetime distributions - continuous models, discrete models, a general formulation; some important models - exponential, Weibull, log-normal, log-logistic, gamma distributions, log-location-scale models, inverse Gaussian distributions re models, mixture; Regression models.

Observation schemes, censoring, and likelihood: right censoring and maximum likelihood; other forms of incomplete data; truncation and selection effects; information and design issues.

Nonparametric and graphical procedures: nonparametric estimation of survivor function and quantiles; descriptive and diagnostic plots; estimation of hazard or density functions; methods of truncated and interval censored data; life tables.

Inference procedures for parametric models: inference procedures for exponential distributions; gamma distributions; inverse Gaussian distributions; grouped, interval censored, or truncated data; mixture models; threshold parameters; prediction intervals.

Inference procedure for log-location-scale distributions: inference for location-scale distributions; Weibull and extreme-value distributions; log-normal and log-logistic distributions; comparison of distributions; models with additional shape parameters; planning experiment for life tests.

Parametric regression models: introduction to log-location-scale regression models, proportional hazards regression models; graphical methods and model assessment; inference for log-location-scale models; extensions of log-location-scale models; hazard based models.

Brief introduction to Cox's proportional hazards model. Partial likelihood function, estimation and interpretation of model parameters.

Text Books

1. Lawless J (2003). Statistical models and methods for lifetime data, *second edition*. Wiley.
2. Kalbfleisch J and Prentice R (2003). The statistical analysis of failure time data, *second edition*. Wiley.

AST 406: Research Methodology and Social Statistics

Credit 4

Research Methodology

Concept, aims and objectives of research; types of research; steps involved in research: qualitative and quantitative; selection and formulation of research problems; proposal writing; examining the designs of some known researches. Questionnaire, check lists, FGD guidelines etc; preparation of questionnaires; preparation of manuals for interviewer; enumerators training, monitoring and supervision for controlling the quality of data; how to avoid non-response. Report writing; content and organizations of the report; heading and subheadings; techniques of writing conclusion, summary, recommendations, footnotes references, appendix, etc; examining some local and international reports.

Concept of monitoring and evaluation (M & E): objectives, usefulness and scope of M & E; views of different schools on M & E; performance monitoring versus performance evaluation. Baseline, ongoing and end line evaluation; impact evaluation; M & E of ongoing programs (activities, inputs, outputs, effect); follow-up for remedies, and post-programs evaluation. Monitoring and evaluation plan and data sources: Indicators for monitoring and evaluation; identification of indicators and characteristics of ideal indicators; factors influencing indicator selection;

Social Statistics

National income: concepts and methods of measurement; social accounting matrix; theoretical distribution of income and wealth: Pareto and Lognormal distribution of income ; Concept, meaning, measurement of positive and normative measures of inequality; Lorenz curve; Gini coefficient; Atkinson's index, Theil's index, Herfindahl index, Human development index etc; desirable properties of a measures of inequality.

Poverty: Concept, definition, and issues of poverty; approach for drawing poverty line income; measurement of different poverty indices; Foster, Greer and Thorlock's general class of poverty measure.

Introduction to psychometrics: measurement in psychology and education; intelligent and achievement tests; test scores; equivalence of scores; Z-score and T-score; intelligent quotient.

Definition, nature and importance of anthropology; role and functions of family.

Social inequality: inequality by sex, age, rank, caste, race, class, power, rule and social connections.

Text Books

1. Blankenberg F (1993). Introduction into the planning, monitoring and evaluation system, April, Dhaka.
2. Bhola S (1990). Evaluating literacy for development, projects, programs and campaigns. UIE and DSE, UIE Handbook and Reference Book 3, Hamburg.
3. Atkinson AB (1978). The Economics of inequality. Clarendon.
4. Sen A (1978). On Economic Inequality. Clarendon.
5. Sen A (1982). Poverty and Famines: An Essay on Entitlement and Deprivation. Clarendon.
6. Rahman MPk (1994). Poverty Issues in Rural Bangladesh. University Press Limited, Dhaka.
7. Elifson KW, Runyon R and Haber A (1981). Fundamentals of Social Statistics. Addison-Wiley.

AST 407: Analysis of Time Series | **Credit 3**

Introduction and examples of time series; simple descriptive techniques: time series plots, trend, seasonal effects, sample autocorrelation, the correlogram, filtering.

Probability models: stochastic processes, stationarity, second-order stationarity, white noise model, random walks, moving average (MA) processes, autoregressive (AR) processes, ARMA processes, seasonal ARMA processes, the general linear process; properties, estimation and model building, diagnostic checking.

Forecasting: naive procedures, exponential smoothing, Holt-Winters, Box- Jenkins forecasting, linear prediction, forecasting from probability models.

Non-stationary time series: non-stationarity in variance - logarithmic and power transformations; non-stationarity in mean; deterministic trends; integrated time series; ARIMA and seasonal ARIMA models; modelling seasonality and trend with ARIMA models.

Stationary processes in the frequency domain: the spectral density function, the periodogram, spectral analysis.

Concept of State-space models: dynamic linear models and the Kalman filter.

Text Books

1. Brockwell PJ and Davis RA (2002). Introduction to time Series and forecasting
2. Chatfield C (2003). The analysis of time series, *sixth edition*. Chapman & Hall.
3. Shumway RH and Stoffer DS (2011). Time series analysis and its applications with R examples. Springer.

AST 408: Generalized Linear Models | **Credit 3**

Generalized linear models: exponential family of distributions; estimation: method of maximum likelihood, method of least squares, estimation of generalized linear models; inference: sampling distribution for scores, sampling distribution for maximum likelihood estimators, confidence intervals for model parameters, adequacy of a model, sampling distribution for log-likelihood statistic, log-likelihood ratio statistic (deviance), assessing goodness of fit, hypothesis testing; multiple regression: maximum likelihood estimation, log-likelihood ratio statistic.

Models for binary responses: probability distributions, generalized linear models, dose response models, general logistic regression, maximum likelihood estimation

and log-likelihood ratio statistic, other criteria for goodness of fit, least square methods; multinomial distributions; nominal logistic regression models; ordinal logistic regression models.

Models for count data, Poisson regression and log-linear models: probability distributions, maximum likelihood estimation, hypothesis testing and goodness of fit.

Text Books

1. Dobson A (2008). An introduction to generalized linear models, *third edition.* Chapman & Hall. .

AST 430: Statistical Computing IX — **Credit 2**

Inference, principal component analysis, factor analysis, discriminant analysis, canonical correlation analysis.

AST 431: Statistical Computing X — **Credit 2**

Fitting ARIMA, ARMA, fitting econometric models.

AST 432: Statistical Computing XI — **Credit 2**

Fitting survival models, logistic, log-linear models.

AST 440: Oral IV — **Credit 2**

AST 450: B.S. Project — **Credit 3**

Each student will be required to prepare a project report and present the report in a seminar. For the project work, each student will be assigned to a teacher at the beginning of the academic year. Submission and evaluation should be made before the commencement of final examination. Fifty percent weight of the course will be allotted to project work, ten percent for supervisor and the remaining forty percent will be for seminar presentation. The internal members of the examination committee will evaluate the performance in the seminars and the report will be evaluated by two internal examiners nominated by the examination committee. A supervisor cannot evaluate the project report s/he has supervised.
