University of Dhaka
Department of Statistics
Syllabus for 4-year B.S. (Honors)
Starting Sessions: 2013-2014 to 2014-2015

The B.S. (Hons.) degree in statistics under the Faculty of Science, Dhaka University, is a 4-year program consisting of four academic sessions. The students enrolled in B.S. (Hons.) in statistics will have to complete a total of **140** credits in 4 years. Each course will comprise of 70% marks for the final exam and 30% marks for the in-course assessment. There will be some Practical (Data Analysis) courses to learn the applications of statistical techniques. For the practical courses, there will be 40% marks for the in-course assessment and the remaining 60% for the final examination. As a part of the incourse assessment, 5% marks will be awarded on the basis of attendance under prescribed rules of the Science Faculty.

The year-wise distribution of credits is as follows:

First Year:	27 credits
Second Year:	36 credits
Third Year:	37 credits
Fourth Year:	40 credits
Total:	**140 credits**

List of Courses

First Year:

Course No.	Course Title	Credit
Stat H-101	Introduction to Statistics	4
Stat H-102	Probability Theory	4
Stat H-103	Principles of Economics	4
Stat H-104	Basic Mathematics	2
Stat H-105	Calculus	4
Stat H-106	Linear Algebra	3
Stat H-107	Statistical Computing I: Basic Statistics and Linear Algebra	2
Stat H-108	Statistical Computing II: Programming with C	2
Stat H-109	Oral Presentation	2
Total		**27**

Second Year:

Course No.	Course Title	Credit
Stat H-201	Sampling Techniques I	3
Stat H-202	Sampling Distribution and Order Statistics	4
Stat H-203	Introduction to Demography	3
Stat H-204	Economic Statistics	3
Stat H-205	Simulation	3
Stat H-206	Industrial Statistics and Official Statistics	3
Stat H-207	Operations Research	3
Stat H-208	Ordinary Differential Equation & Analytical Geometry	3
Stat H-209	Mathematical Methods	3
Stat H-210	Statistical computing III: Sampling Techniques I & Economic Statistics	2
Stat H-211	Statistical computing IV: Numerical Mathematics and Operations Research	2
Stat H-212	Statistical computing V: Programming with R	2
Stat H-213	Oral Presentation	2
Total		**36**

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Third Year:

Course No.	Course Title	Credit
Stat H-301	Theory of Estimation	4
Stat H-302	Test of Hypothesis	4
Stat H-303	Sampling Techniques II	4
Stat H-304	Regression Analysis	4
Stat H-305	Categorical Data Analysis	2
Stat H-306	Epidemiology	4
Stat H-307	Mathematical Demography and Actuarial Statistics	3
Stat H-308	ANOVA and Linear Inference	3
Stat H-309	Mathematical Analysis	3
Stat H-310	Statistical computing VI: Introduction to SPSS and Stata	2
Stat H-311	Statistical computing VII: Demography, ANOVA and Regression (Using SPSS and Stata)	2
Stat H-312	Oral Presentation	2
Total		**37**

Fourth Year:

Course No.	Course Title	Credit
Stat H-401	Multivariate Analysis	3
Stat H-402	Introduction to Robust Statistics	3
Stat H-403	Design and Analysis of Experiment	4
Stat H-404	Econometrics	3
Stat H-405	Biostatistics	4
Stat H-406	Introduction to Artificial Intelligence	3
Stat H-407	Research Methodology	3
Stat H-408	Stochastic Process	3
Stat H-409	Time Series Analysis	4
Stat H-410	Comprehensive	2
Stat H-411	Statistical computing VIII: Multivariate Analysis and Experimental Design (using R and Stata)	2
Stat H-412	Statistical computing IX: Biostatistics and Robust Statistics (Using R and Stata)	2
Stat H-413	Statistical Computing X: Econometrics and time series (Using R and Stata)	2
Stat H-414	Oral Presentation	2
Total		**40**

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Detailed Syllabus

First Year B.S. (Hons.)

Stat H-101: Introduction to Statistics **4 credits**

Statistics – definition and scope: Definitions of statistics - past and present, its nature and characteristics, population and sample, descriptive and inferential statistics, scope and applications of statistics, abuse of statistics, sources of statistical data, primary and secondary sources, data collection tools, types, etc., construction of questionnaire and other field problems of data collection, types of data, cross sectional, longitudinal, follow-up and panel data.

Processing of data: Measurement scales, variables, attributes, classification, characteristic and basis of classification, array formation, tabulation, different types of tables, frequency distribution.

Presentation of data: Graphical presentation of data, details of different types of graphs and charts with their relative merits and demerits, concept of explorative data analysis, stem-and-leaf plot, schematic plots, extremes and median, hinges, outliers and 5-number summaries.

Characteristics of statistical data: Measures of location, dispersion, skewness, kurtosis and their properties, moments, box-and-whiskers plots, trimean, trimmed mean, interpretation of data with these measures.

Correlation analysis: Bivariate data, scatter diagram, simple correlation, rank correlation, correlation ratio, intraclass and biserial correlation.

Regression analysis: Basic concept of regression, regression model, estimation of parameters (OLS method) in regression model, properties of estimators, interpreting the constants.

Association of attributes: Concepts of independence, association, contingency table, measure of association for nominal and ordinal data in contingency tables.

Texts

1. Ross, S. M. (2010), *Introductory Statistics*, 3rd Ed.
2. Islam, M. N. (2011), *An Introduction to Statistics and Probability*, 4th Ed..
3. Jalil, A. and Ferdous, R. (1999), *Basic Statistics Methods and Applications*.

References

1. Larson, R. and Farber, B. (2003), *Elementary Statistics*, Prentice-Hall, Inc.
2. Mostafa, M.G., *Methods of Statistics*.
3. Steel, R.G.D., Torrie, J.H. and Dickey, D.A. (1997), *Principles and Procedures of Statistics,* 3rd Ed.,
4. Wesis, N. (2007) Introduction to Statistics, 7th edition, Addisos Wiley.

Stat H-102: Probability Theory **4 credits**

Elements of set theory: Fundamentals of set, operations with set, laws of set.

Elements of probability: Experiment, random experiment, sample space, events, event space, union and intersection of events, different types of events.

Basic concepts of probability: Different approaches of defining probability – classical, axiomatic, empirical and subjective, laws and theorems of probability, conditional probability, Bayes' theorem and its uses and importance in statistics.

Random variable and its probability distribution: Discrete and continuous random variables, probability mass function, probability density function, distribution function, function of random variable and its distribution, joint distribution, marginal and conditional distributions, independence of random variables.

Mathematical expectation: Concept, expectations of sums and products of random variables, conditional expectation and conditional variance, moments and moment generating functions, cumulants and cumulant generating functions, relation between moments and cumulants, probability generating functions, characteristic function.

Some basic distributions: binomial, Poisson, normal, uniform, geometric, negative binomial, hypergeometric, exponential, gamma, beta distributions.

Chebyshev's inequality.

Texts

1. Ross, S. (2008). *A First Course in Probability*, Pearson.
2. Islam, M.N. (2011). *An Introduction to Statistics and Probability*, Book World, Dhaka.

References

1. Hoq, S. (1996), *Probability: An Introduction.*
2. Roy, M.K. (1996), *Fundamentals of Probability and Probability Distribution.*
3. Uspensky, J.V., *Introduction to Mathematical Probability.*
4. Cramer, H., *The Elements of Probability*, Wiley and Sons, N.Y.
5. Feller, W., *Introduction to Probability Theory and Its Applications*, Wiley and Sons, N.Y.
6. Ayres, F., *Set Theory*, Schaum Series, McGraw-Hill.
7. Pattel, K., Kapadia, and Owen, D.B., *Handbook of Statistical Distributions.*

Stat H-103: Principles of Economics **4 credits**

Basic Concepts: definition and scope of economics, basic economic problems and their sources, choice, opportunity cost, economic systems - command economy, market economy and mixed economy; microeconomics and macroeconomics; normative economics and positive economics.

Demand and supply: definition, factors influencing them, demand and supply schedules & curves, law of downward-sloping demand, market demand and market supply, movements along and shifts in demand curve, shifts in supply curve, market equilibrium: price theory in the market, its implications, effects of a shift in demand or supply on equilibrium position.

Elasticity: elasticity of demand and supply - concepts, definitions and problems associated with calculations, price elasticity, income elasticity and cross elasticity of demand, factors influencing them, types of demand curves depending on elasticity of demand, computation of elasticity from demand function and family budget data.

Consumer behaviour and utility: basic concepts, ordinal and cardinal measurements of utility, Total utility and marginal utility, law of diminishing marginal utility, Utility maximization, determination of demand function from utility function and budget constraint. Substitution and income effects and the law of demand. Slutsky equation, computation of elasticity from Slutsky equation. The paradox of value.

The indifference curve analysis: Concepts, consumer's indifference curve: properties, rate of commodity substitution. consumer's equilibrium, effects of income and price change on equilibrium.

Market Mechanism: Market structure, Perfect and imperfect competition, Monopoly: pure monopoly, Monopolistic competition. Oligopoly: duopoly, Short-run and long-run equilibrium analysis in perfect competition.

Pricing of the factors of production: Least-cost rule. Distribution by Marginal products-Clark's theory. Marginal productivity theory of Income distribution, Theories of Wage, Rent, Interest and Profit.

Theory of income distribution: Macroeconomic concepts, Savings, Investment, Employment and National income with reference to keynesian economics.

Division of labour. Localization of industries.

Texts

1. Samuelson, P.A., *Economics*, 10th Ed., McGraw-Hill Inc.
2. Samuelson, P.A. and Nordhaus, W.D., *Economics*, 16th Ed., McGraw-Hill Inc.
3. Varian, H.R., *Intermediate Microeconomics: A Modern Approach,* 3rd Ed., W.W. Norton & Company.

References

1. Lipsey, R.G. and Crystal, K.A., *An Introduction to Positive Economics*, Oxford University Press.
2. Colander, C., *Microeconomics*, 3rd Ed.
3. Ferguson, C.E. and Gould, J.P., *Microeconomic Theory.*

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Stat H-104: Basic Mathematics **2 credits**

Sets and subsets. Set operations. Family of sets. De Morgan's laws. Relations and functions: Cartesian product of sets. Relations. Equivalence relations. Functions. Images and inverse images of sets. Injective, subjective and bijective functions. Inverse functions. The Real number system: Field and order properties. Natural numbers, integers and rational numbers. Absolute value. Basic inequalities, (including inequalities involving means, powers; inequalities of Cauchy, Chebyshev, Weierstrass).
Summation of finite series: Arithmetic-geometric series. Method of difference. Successive differences.
Theory of equations: Synthesis division, Number of roots of polynomial equations. Relations between roots and coefficients. Multiplicity of roots. Symmetric functions of roots. Transformation of equations.
Geometry: Graphical solutions of simultaneous, quadratic and cubic equations, graphs of logarithmic, exponential, conic functions, graphs of basic probability distribution etc.Convergence and divergence of a series. Different tests for convergence, Absolute convergence etc.

Texts:
1. John Bird (2005): Basic Engineering Mathematics 4th ed. Elsvier, Amstendam.
2. Ayres, F(1995). Theory and Problems of modern Algebra, McGraw-hill.

References
1. S.Lipschutz, Set Theory, Schaum's Outline Series.
2. S. barnard & J.M. Child, Higher Algebra.
3. W.L. Ferrar, Algebra.
4. P.R. Halmos, Naïve Set Theory.
5. Durall & Robson, Differential Calculas.

Stat H-105 : Calculus 4 credits

Group A: Differential Calculus

Functions and their graphs (polynomial and Rational functions, logarithmic and exponential functions, trigonometric functions and their inverses, hyperbolic functions and their inverses, combination of such functions). Limits of Functions: definition. Basic limit theorems (without proofs). Limit at infinity and infinite limits. Continuous functions on closed and boundary intervals (no proofs required). Differentiation: Tangent lines and rates of change. Definition of derivative. One sided derivatives. Rules of differentiation (with applications). Linear approximations and differentials. Successive differentiation. Leibnitz theorem. Rolle's theorem: Lagrange's mean value theorems. Extrema of functions, problems involving maxima and minima.
Vector-valued functions of a single variable: Limits, derivatives and integrals of vector valued functions. Tangent lines to graphs of vector valued functions. Curvature of plane and space curves. Partial differentiation: Functions of several variables. Limits and continuity. Partial derivatives with constrained variables. Directional derivatives; gradient vectors and tangent planes.
Taylor's formula (in one and in several variables). Extrema of functions of several variables, Lagranges multiplier.
Examples of applications in Statistics.

Group B: Integral Calculus

Integrals: Antiderivatives and indefinite integrals. Techniques of integration. Definite integration using antiderivatives.
Definite integral as a limit of a sum. The fundamental theorem of calculus. Integration by rwduction.
Application of integration: Plane areas. Solids of revolution. Volumes by cylindrical shells. Volumes by cross-sections. Arc length and surface of revolution. Multiple integrals: Double and triple integrals; and iterated integrals. Area as a double integral. Double integrals in polar form . Volume as a triple integral. Triple integral in cylindrical and spherical polar coordinates.
General multiple integrals. Change of variables in multiple integrals. Jacobians. Examples of applications in statistics.

Texts:
1. Stewant, J(2006): Calculus: eanly transcendental(Stewant's calculus series)
2. Rdwanls,J(1994) Differential Calculus, Macmillan,London.5th edition, Wiley.

References
1. H. Anton et al, Calculus with Analytic Geometry.
2. E.W. Swokowski, Calculus with Analytic Geometry.
3. L. Bers & P.Karal, Caqlculus.
4. S. Lang, A first Course in Calculus.
5. S. Lang, Calculus of several variables.

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Stat H-106: Linear Algebra **3 credits**

Vector and Vector Set: Definition of a vector, different types of vectors, geometrical interpretation, length and angle between two vectors, operation with vectors, vector set, linearly dependent and independent set of vectors, sweepout method, orthogonal set, normalization, Gram-Schmidt orthogonalisation process, subset and superset of vectors, related theorems.

Vector spaces: Spanning set of vectors, vector spaces and sub-spaces, their geometric interpretation, rank and basis of vector spaces and sub-spaces, orthogonal and orthonormal basis, related theorems.

Determinants: Matrix and vector, square matrix and determinants, ideas of minors and co-factors, product of determinants, properties of determinants, different types of determinants, solution of equations with the help of determinants, evaluation of $n \times n$ determinants.

Matrices: Definitions with examples, different types of matrices: orthogonal, idempotent etc., matrix operations, properties of such operations, rank and elementary transformation of matrices, diagonal reduction of a matrix, related theorems of ranks, trace of a matrix, its properties with proofs.

Inverse of a matrix: Definition with examples, different methods of finding inverse of a matrix, properties of such inverses with proofs.

System of linear equations: Introduction, types of linear equations - homogeneous system, non-homogeneous system, consistent and inconsistent unique solution, different methods of solution of such equations: Gaussian elimination. Cramer's rule, sweep-out method, using matrix inverse, related theorems on system of linear equations.

Generalised inverses (g-inverses): Definition, methods of finding g-inverses, properties of g-inverses existence, uniqueness, other properties, kinds of g-inverses, application of g-inverses in the solution of system of equations.

Kronecker sum and product of matrices: Operational conformability of matrices and vectors, definitions of Kronecker sum and product of matrices and vectors of different orders, their examples, properties of Kronecker products with proofs, their uses.

Quadratic forms: Definition with examples, classification of quadratic forms, latent roots and latent vectors of matrices, canonical form of a quadratic form, rank, index and signature, related theorems of eigen values, eigen vectors and quadratic forms.

Texts

1. Hadley, G. (1993), *Linear Algebra*, Narosa , New Delhi.
2. Graybill, A. (1982), *Matrics with Application in Statistics*, Wadsworth & Co. 2nd Ed., N.Y.
3. Anton,H. and Rorres, C(2005):Elementary Linear Algebra,4th edition, Wiley.

References

1. Rahman, A. (2006), *College Linear Algebra.*
2. Searle, S.R.(1982), *Matrix Algebra useful for Statistics*, Wiley, N.Y.
3. Santinarayan, (1985), *A Text Book of Matrices*, 8th Ed., S. Chand and Co., New Delhi.
4. Searle, S.R., *Linear Models*, Wiley, N.Y.
5. Rao, C.R. and Mitra, *Generalised Inverses and Its Applications.*
6. Franklin, A.B., *Matrices with Applications in Statistics*, Wordsworth International Group.
7. Schaum Series (1981), *Linear Algebra.*
8. Aitken, A.C. (1982), *Determinant and Matrices*, Oliver and Boyd, London.

Stat H-107: Statistical Computing I: Basic Statistics & Linear Algebra **2 credits**

Condensation and tabulation of data, Frequency distribution, Graphical representation of data, Measures of location and dispersion, Calculation of moments, Measures of Skewness and Kurtosis, Exploratory data analysis, Simple correlation co-efficient and fitting of regression lines, Rank correlation, Correlation ratio, Intraclass correlation, Multiple and partial correlation co-efficients, contingency table.

Vector spaces & sub spaces: their rank, basis, etc., finding orthonormal and independent vectors, Sweepout Method, Gram-Schmidt Orthogonalisation process, matrix product, inversion of matrix by different methods, ranks, latent roots and latent vectors of a matrix, reduction of matrices to diagonal forms and canonical forms, solution of equations, g-inverse, quadratic forms etc.

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Stat H-108: Statistical Computing II: Programming with C **2 Credits**

Fundamentals – algorithms, flowcharts, program, programming languages: machine level, assembly level and high level languages, execution of programs: translator, compiler, interpreter and assembler, operating systems.

Introduction to C – importance and origin of C, simple C programs: compiling and running, basic structure of C programs.

Variables, data types, constants, arithmetic expressions, declaration of variables, assignment statements, relational operations, logical operations, conditional statements: if, switch etc., program looping: for, while etc., arrays, functions, structures, character strings, pointers.

Using C programs for statistical computations.

Texts

1. Dietel, P.G. and Dietel, H.M. (2010). C how to program, 7th Ed. Pearson.
2. Kochan, S.G. (2005). Programming in C, 3rd Ed. Sams Publishing.

Stat H-109: Oral Presentation 2 Credits

Second Year B.S. (Hons.)

Stat H-201: Sampling Techniques 1 **3 credits**

Introduction: Basic concepts of sampling, sampling frame, sample survey versus census, requirements of a good sample, selection bias, measurement bias, sampling and non-sampling errors, probability and non-probability samples, types of probability samples, framework for probability sampling

Simple Probability Samples: Simple random sampling, estimates of population characteristics, standard errors, confidence intervals, sampling for proportions, randomization theory results for simple random sampling, a model for simple random sampling, situations where a simple random sample is appropriate.

Ratio estimation: Use of auxiliary data in ratio estimation, regression estimation, regression models, design implications of regression models, comparison of ratio and regression estimation method.

Systematic Sampling: Estimation of population characteristics, systematic sampling in some special population.

Stratified Sampling: Definition and basic ideas, theory of stratified sampling, allocating observations to strata, a model for stratified sampling, post-stratification, stratified versus quota sampling.

Cluster sampling with equal Probabilities: Notation for cluster sampling, one-stage cluster sampling, designing a cluster sample, models for cluster sampling. Comparison with simple random sampling and systematic sampling. Determination of optimum cluster size. Stratified cluster sampling.

Sampling with Unequal Probabilities with replacement: One-stage sampling with replacement, two-stage sampling with replacement, examples, randomization theory results and proofs, models for unequal-probability sampling with replacement.

Sample size: Concept of sample size estimation. Determination of sample size for estimating mean and proportions. Design effect, sample size for comparisons of two means or proportions.

Texts

1. Lohr, S.L. (2005), *Sampling:* Design and Analysis
2. Islam, M.N. (2008) *An Introduction to Sampling Methods* Book World

References:

1. Cochran, W.G. Sampling Techniques
2. Levy, P.S. and Lemeshow, S, Sampling of Populations
3. Kish, L., Survey Sampling
4. Singh, D and Chaudhury, F.S. Theory and Analysis of Sample Survey design.

5. Hendelhall, Ott, and Scaeffer, Elementary Survey Sampling
6. Sukhatme, P.V. Sampling theory of Surveys with Application, 2nd Ed. Asia Publishing House, London.
7. Yates, F, Sampling Methods for Censuses and Surveys.

Stat H-202: Sampling Distribution and Order Statistics **4 credits**

Group A: Sampling Distribution

Functions of random variables and random vectors: Method of distribution functions, method of transformations, Method of moment generating functions, Probability integral transform.

Distribution of sum, difference, product and quotient of random variables, functions of random vectors of continuous and discrete type, Central Limit Theorem with applications, Inversion Theorem.

Sampling distributions: Definition, examples from discrete and continuous populations, difference from probability distribution,

Different methods of finding sampling distribution: Analytical method, inductive method, geometrical method, method of using characteristic function, etc. Distribution of sample mean and variance and their independence for normal population, χ^2, F and t distributions (central and non-central cases), their uses in statistics. Sampling Distribution of correlation and regression coefficients, Derivation of frequency χ^2

Standard errors of statistics and their large sample approximations. Transformation of variables including square root, log, sin-inverse etc.

Group B: Order Statistics

Definition and distributions of functions of order statistics for both discrete and continuous cases, asymptotic distributions, sample cumulative distribution functions, distribution of a single order statistics, joint distribution of order statistics, distribution of range and some other statistics.

Texts

1. Hogg, R.V. & Craig, A.T., *An Introduction to Mathematical Statistics*, McMillan-Collierm, N.Y.
2. Mood, Graybill & Boes, *Introduction to the Theory of Statistics*, 3rd Ed., McGraw-Hill.

References

1. Gupta, S.C. and Kapoor, V.K., *Fundamentals of Mathematical Statistics.*
2. Balakrishman, N. & Cohen, A. C., Order Statistics and Inference: *Estimation Methods*, Academic Press, Boston.
3. Hoel, P.G., *Introduction to Mathematical Statistics*, Wiley, N.Y.
4. Rao, C.R., *Linear Statistical Inference & its Applications*, Wiley.
5. Steel and Torrie, *Principle and Procedures of Statistics.*

Stat H-203: Introduction to Demography **3 credits**

Basic Concepts: Population studies and demography, scope of demography, population and demographic variables

Sources of demographic data: Primary and secondary sources. Vital registration, Survey and Census.

Demographic **rates and ratios:** Concepts of rates, ratios, proportions and probability. Crude rates and refined rates, Age-Sex composition, population pyramid, cohort and Lexis diagram.

Population change: Concept of population change, population growth, measurement of population growth.

Fertility and reproduction: Concept of fertility, reproduction, fecundity, fecundability, sterility. Measurements of fertility and reproduction, cohort fertility, parity progression ratio, differentials of fertility.

Mortality: Concepts of mortality and morbidity, measures of mortality, trends in mortality, differentials of mortality, measures of morbidity. Standardization.

Marriage: Concept of marriage, estimation of mean and median age at marriage, estimation of singulate mean age at marriage, Coals indices (I_g, I_f, and I_m), their relationships and contributions to fertility differentials.

Migration: Concept, types and measures of migration. Consequence, determinants and trends of migration.

Texts

1. Shryock, H.S., Siegel, J.S. et al., *The Methods and Materials of Demography.*
2. Andrew Hinde. *Demographic methods.*
3. Barcley, G.W., *Techniques of Population Analysis.*

References

1. Specigelman, *Introduction to Demography.*
2. Pollard, A.H., Farhat, Y. & Pollard, G.N., *Demographic Technique.*
3. Namboodiri, M.K. & Suchindran, C.M. (1987), *Life Table Techniques and their Applications*, Academic Press, London.
4. Kpedekpo, G.M.K., *Estimates of Demographic Analysis for Africa.*
5. Chiang, C. L., *The Life Table and its Application.*
6. *United Nations: Manuals I to XI.*
7. Biswas, S., *Stochastic Process in Demography and Application*, Wiley Eastern Ltd.
8. Pressat, R., *Word Book in Demography* (Latest Ed.), Nethuen, London.
9. Journals: *Population Studies, Demography, Population and Development Review, Studies in Family Planning, Asia-Pacific Population Journal.*

Stat H-204: Economic Statistics 3 credits

Theory Of Firms

Firms technology. Contrasts and similarities between firms and consume behavior analysis. Production function and its properties. Returns to scale. Productivity curves: total, average and marginal productivity curves along with their characteristics, Stages of production. Time horizons of decision making: short run, long run and very long run. Isoquants. Marginal rate of technical substitution(MRTS). Diminishing MRTS. Output elasticity of inputs. Isocost lines. Ridge lines. Firms optimization behavior: constrained output maximization, constrained cost minimization and profit maximization. Producers equilibrium. The expansion path. Isoclines. Euler's theorem. Linearly homogeneous production function. Cobb-Douglas(CD) production function with properties and estimation. Constant elasticity of substitution(CES) production function.

Cost Of Production

Costs of production-fixed and variable, total and marginal costs, Nature of cost. Cost function and curves: short run and long run. Diminishing return and short run costs. Marginal average rule. Long run cost curves as an envelope of short run cost curves. Economics of scale of long run average cost. Statistical studies of long run average cost curves. Cost and profit functions with variable factor prices.

Distribution Of Income

Pareto and log-normal income distribution: properties, fitting, determination of parameters, implications and limitations. Concentration curve: Lorenze curve and equation, Gini's concentration ratio. Engel's law and curve. Fitting of Engel's curve from family budget data.

National Income

Concept. Gross Domestic Product, Gross National Product, Net National Product, National Income, Personal Income, Disposable Income, measurements and problems. Difficulties in the estimation of Gross National Product (GNP).

Index Numbers

Definition and necessity. Different types of index numbers: Simple and weighted indices, Test of index numbers. Cost of living index. Constructions of Different types of cost of living index.

Texts

1. Samuelson, P.A., *Economics.*
2. Varinn, H.R., *Microeconomic Theory.*
3. Henderson and Quandt, *Microeconomic Theory.*

References

1. Varian, H.R., *Intermediate Microeconomics.*
2. Gupta and Kapoor, *Applied Statistics.*
3. Davis, *Economic Statistics.*

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4. Prashar, S. and Singh, *Econometrics and Mathematical Economics.*
5. Wonnacott and Wonnacott, *Econometrics.*
6. Dominick Salvatore, *Theory and Problems of Microeconomic Theory.*
7. Croxton and Cowden, *Practical Business Statistics*

Stat H-205 Simulation **3 Credits**

Introduction, definition, principles of Monte Carlo methods; techniques of generating pseudo random numbers, testing the randomness; generating random samples: direct method, indirect method, Accept/Reject algorithm; generating data from binomial, Poisson, exponential, beta etc.; generating data from normal: Box-Muller algorithm, Marsaglia methods, correlated random variables.

Texts
1. Naylor, T.H. (1966), *Computer simulation techniques.* Wiley.
2. Glasserman, P. (2004), *Monte Carlo Methods in Financial Engineering,* Springer.

Stat H-206 Industrial Statistics and Official Statistics **3 Credits**

Industrial Statistics and quality Control: Nature and scope, production and Realisation statistics. Sources of Industrial statistics, labour statistics and working time, etc. Indicator (mobility of labour, etc.) of output statistics, statistics of fixed investment, expenditure statistics, Production cost statistics. Identification of quality level. Quality and its relation to product sortness, Study of wastages. Utilization of labour resources. Productivity of labour. Quality control measures. Statistical quality control techniques, its uses and usefulness. Product control and process control. Assignable and non-assignable sources of variation. Basic concepts of control charts. Construction of control charts (variable and Attribute). Natural tolerance and specification limits. Acceptance sampling. Derivation of Sampling plans (single and double). OC and ASN curves.

Official statistics: Sources, Problems of official statistics. Methodological issues, sources and limitations, some National and International statistical publications, recommendations. Specific examples from **BBS,** planning. Commission, Bangladesh **Bank,** etc.

Texts:
1. Duncan, A.J. –Quality control and Industrial Statistics
2. BBS Publications.

References:
1. Dodge and Roming- Sampling inspection tables: Single and Double Sampling.
2. Grant, E.L., -Statistics Quality Control.
3. Croxtion and Cowden –Practical Business Statistics.
4. Wessel, Wellet and Simons –Statistics as applied to Economics and Business.
5. Wetherill, G.B. (1977)- Sampling Inspection and Q.C. Chapman & Hill.
6. Gupta and Kapur- Applied Statistics.

Stat H-207 Operations Research **3 Credits**

Linear Programming: Introductions: Formulations of linear programming problems. Graphical Solutions of two variables problems. Principal theorems of Linear Programming, Simplex Method, Revised Simplex Method, Dual Simplex Method, Two-phased Method, Big.-M. Method.
Game Theory: "Two persons zero sum" game, Pure, Mixed and Optimal Strategy, Relationship between two person zero sum game and linear programming symetric games.

Integer Linear Programming: Formulation of Integer Linear Programming Problem by cutting plane and branch and Bound methods, Solution of mixed integer, Integer programming problem by cutting plane method.

Inventory Models: Deterministic Models. Single Item Static Model. Single Item Static Model with Price Breaks, Multiple Item Static Model with Storage Limitation.

Transportation Problem: Basic feasible solution of transportation problem, Optimality test, Degeneracy, UnleaLanced, Variations and Least time transportation problem, Transhipment problem, Assignment problem.

Texts
1. Vajda, S. (2009), Mathematical Programming.
2. Duncan, A.J. (1986), Quality Control and Industrial Statistics.

References
1. Dantzig. B., *Linear Programming and Extension.*
2. Gass, S.I., *Linear Programming*, McGraw-Hill.
3. Hadly, G., *Linear Programming*, Addison Wesley.
4. Hadly, G., *Analysis of Inventory Systems*, Prentice-Hall, International, N.Y.
5. Kohlas J., *Stochastic Methods of Operations Research*, CUP, London.
6. Taha, H.A., *Operations Research: An Introduction*, Coll-Macmillan International Editions.
7. Dodge and Roming, *Sampling Inspection Tables: Single and Double Sampling.*

Stat H-208 Ordinary Differential Equation & Analytical Geometry **3 Credits**

Group-A: Differential Equations

Ordinary differential equation (ODE) of first order and first degree, variable separable, Homogeneous and non-homogeneous equations, Exact differential equations, Simple cases of differential equations of first order and of degree higher than one, Linear differential equations with constant coefficient, Ordinary simultaneous differential equations, equations reducible to homogeneous forms, Homogeneous linear equations, orthogonal trajectories. Partial differential equations: first order, second order (Linear and non-linear) and their analysis in details.

Group-B: Analytical Geometry

Co-ordinate geometry of two Dimensions:Transformation of axes; Equation of pair of straight lines, General equation of second degree; circle, parabola and hyperbola (tangents, normal chord of contract, pole), System of circles, Ellipse.
Geometry of three Dimensions: Cartesion co-ordinate; Equation of plane, straight line, Sphere, Hyperboloids and Paraboloids, General equation for second degree in three variables. Some ideas of Geometry of n-dimensions.

Texts:
1. Ross, S.L. (1980): Introduction to ordinary differential equations, 4th edtion. Wiley.
2. Anton, H(2000): Calculus with Analytic Geometry, Wiley, N.Y.

References
1. Ayres,Franck: Theory and problems of differential equation
2. Farid, S.M.:Differential Equation & tensor Analysis.
3. Durall & Robson: Alebra Vol. I, II, & III
4. Mohammad, K.- Analytic Geometry and Vector Analysis.
5. Abdur Rahman, A.F.M. & Bhattacharjee, P.K.- Analytic geometry and Vector Analysis.

Stat H-209 Mathematical Methods **3 Credits**

Group A: Numerical Mathematics

Differences of a polynomial, finite difference operators, interpolation and extrapolation by different formulae, inverse interpolation, numerical differentiation, numerical integration by different formulae, the accuracy of quadrature formula, numerical solution of equations by various methods, double interpolation.

Group B: Advanced Calculus

Beta and gamma function and their properties; incomplete beta and gamma function; Jacobian of transformation, Lagrange's multipliers. Taylor's expansion and uses in statistics.

Fourier series: Dirichlet conditions; odd and even functions; half range, Fourier sine or cosine series; parseval's identity; differentiation and integration of Fourier series.

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Laplace transform: definition; 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; 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.

Texts:

1. Mallick, S.A. and Uddin, M. A. (2007), *Numerical mathematics*.
2. Rahman, M.A. (2001), *A College Mathematical Methods*, second edition. Nahar Book Depot.
3. Agarwal, D. *Advanced Integral Calculus*.

Refernce:

1. Burden, R.J and Faires,JD(2010): Numerical Analysis, 9th ed. Brooks Cole.
2. Speigel, M.R. (1965): Schaum's outlines of Laplace Transfrom's, McGraw-Hill.
3. Wrede,R and Speigel M.R. (2010): Schaum's outlines of Advanced Calculus, 3rd ed. McGraw-Hill.

Stat H-210 Statistical Computing III : Sampling Techniques I & Economic Statistics **2 Credits**

Sampling Techniques: drawing a simple random sample, systematic sample, stratified random sample, estimation and standard errors; drawing one-stage and two-stage cluster samples with equal and unequal probabilities with replacement, estimation and standard errors; sample size estimation for different sampling designs.

Economic Statistics: Optimization behavior, constrained output maximization, constrained cost minimization and profit maximization. Finding producer's equilibrium. Fitting production function: Cobb-Douglas. Fitting income distribution: Pareto and log-normal. Finding Gini's ratio. Fitting Lorenze and Engel's equation and curve.

Stat H-211 Statistical Computing IV: Numerical Mathematics & Operations Research **2 Credits**

Numerical **Mathematics:** Use of interpolation formulae for equal and unequal intervals, Inverse interpolation, Numerical integration, solution of equation.

Operations Research: Formulation of LP problems, graphical solution, simplex method, use of artificial variables, Dual problem and its solution, problems on Game Theory.

Stat H-212: Statistical Computing V: **Programming with R** **2 Credits**

Introduction: an introductory session, case-sensitivity, recall and correction of previous commands, assignments and expressions, simple manipulations of number, getting help with functions and features, executing commands from or diverting output to a file, data permanency and removing objects.

Vectors: Creating vectors, vector arithmetic, generating regular sequences, logical vectors, missing values, character vectors, index vectors; selecting and modifying subsets.

Objects, their modes and attributes: Intrinsic attributes: mode and length, changing the length of an object, getting and setting attributes, class of an object.

Arrays and matrices: Arrays, array indexing, subsections of an array, index matrices, the array() function: mixed vector and array arithmetic, The outer product of two arrays, generalized transpose of an array, matrix facilities: matrix multiplication, linear equations and inversion, eigenvalues and eigenvectors, Forming partitioned matrices, cbind() and rbind(),The concatenation function, c(), with arrays, frequency tables from factors.

Probability distributions: R names for different distributions, obtaining densities, cumulative probabilities, quantiles and random samples from different distributions.

Grouping, conditional execution and loops
Grouped expressions, conditional execution: if statements, repetitive execution: 'for', 'repeat' and 'while'.

Writing your own functions: arguments and defaults, returning multiple objects as output, simple examples including equation solving by Newton-Raphson method.

Texts
1. Venables, W.N. and Smith, D.M., An Introduction to R.

References
1. R reference manual.

Stat H-213: Oral Presentation **2 Credits**

Third Year B.S. (Hons.)

Stat H-301: Theory of Estimation **4 Credits**

Concept of statistical inference: Introduction to Estimation Theory, Problem of estimation, Types of Estimation

Methods of finding Point estimators: Method of moments, Method of Maximum likelihood, Method of minimum distance, Least Square method and Bayes' estimation method, properties of maximum likelihood estimator (MLE), EM Algorithm with example and applications.

Criteria of a good estimator: MSE, unbiasedness. Cramer Rao Inequality, Use of Cramer Rao inequality, Rao Blackwell theorem in finding UMVUE, MVB estimator, Efficient estimator, Consistency, Best Asymptotically Normal, Consistent Asymptotically Normal.

Sufficiency: Sufficient estimator, Factorisation theorem, Application and examples. Families of distributions, exponential family etc., Minimal sufficiency and complete sufficiency, Ancillary statistic and its relation with complete Suff. Statistic and UMVUE. Lehmann-Schefe theorem, Basu's theorem and their applications.

Interval estimation: Introduction, confidence interval and confidence limit, confidence belt and confidence confidence coefficient,

Methods of finding Interval estimators: Inverting a test statistics, Pivotal Quantities, Pivoting the CDF.and Baysian Intervals. Confidence interval for mean, variance, difference of mean, ratio of variance, correlation coefficient, regression coefficient etc. Approximate ML Intervals, Other large sample Intervals.

Texts
1. Hogg, R.V. and Craig, A.T., *Introduction to Mathematical Statistics*, McMillan-Collierm, N.Y.
2. Mood, Graybill and Boes, *Introduction to the Theory of Statistics*, 3rd Ed., McGraw-Hill.

References
1. Casella., G., and Berger, R.L., Statistical Inference, 2nd Ed., Thomson.
2. Rao, C.R., *Linear Statistical Inference and its Applications*, Wiley.
3. Kendall & Stuart, *The Advanced Theory of Statistics*, Vol. I & II.
4. Ferguson, *Mathematical Statistics: A Decision Theoretic Approach.*
5. Gramer, *Mathematical Methods in Statistics.*
6. Cox, D.R. & Hinkley, U., *The Theory of Statistics*, Methuem, London.
7. Lehmann, *Theory of Point Estimation.*

Stat H-302: Test of Hypothesis **4 credits**

Preliminaries of tests: Hypothesis, simple and composite hypotheses, null and alternative hypotheses, concept of test of significance, procedures of a test, errors in testing hypothesis, level of significance, power of test, power function, one-tailed and two-tailed tests, p-value.

Common tests based on normal, χ^2, t and F statistics: Testing the significance of single mean, single variance, single proportion, difference of two means and proportions, ratio of two variances, simple correlation coefficient and regression coefficient. Paired t-test. Testing the homogeneity of several population mean, variance and proportions. Statement about p-values for these tests. Association

of Attributes, Association & disassociation, Measure of association, Attribute, contingency tables, General test of independence in an r × c contingency table. Fisher's exact test for a 2x2 contingency table. Test of goodness of fit.

Evaluating tests: Best critical region and most powerful test, Neyman-Pearson lemma, Uniformly most powerful test, Monotone likelihood ratio test, A decision theoretic view of hypothesis testing.

Likelihood Ratio Test: Introduction, distribution of likelihood ratio, properties, tests for single, double and several means, variance.

Sequential Probability Ratio Test: Introduction, SPRT, Determination of constants, operating characteristic function, Average sample number.

Non-Parametric Tests: Concepts of Non-Parametric tests, useful Non-Parametric tests like sign test, Rank test, Run test, Signed rank test, Median test, Kolmogorov-Smirnov test of Goodness of fit, Kruskal-Wallis test, Rank Sum test, Friedman test.

Texts

1. Hogg, R.V. and Craig, A.T., *An Introduction to Mathematical Statistics*, McMillan-Collierm, N.Y.
2. Mood, Graybill and Boes, *Introduction to the Theory of Statistics*, 3rd Ed., McGraw-Hill.
3. Mendenhall, *Mathematical Statistics*.

References

1. Snedecor, *Statistical Methods*.
2. Islam, M.N. (2006), *An Introduction to Statistics and Probability*, Book World.
3. Mostafa, M.G., *Methods of Statistics*.
4. Anderson, R.L. and Bancorft, T.A., *Statistical Theory in Research*. McGraw-Hill.
5. Ali, A., *Theory of Statistics*, Vol. 2.
6. Hoel, P.G., *Introduction to Mathematical Statistics*, Wiley, N.Y.
7. Rao, C.R., *Linear Statistical Inference & its Applications*, Wiley.
8. Cox, D.R. and Hinkley,U., *The Theory of Statistics*, Methuen, London

Stat H-303: Sampling Technique II **4 credit**

Review of cluster **sampling:** Simple Cluster sampling with unequal sized cluster-estimates, bias, standard error and efficiency. Sampling of unequal clusters with unequal probability with replacement. The Hovitz-Thompson estimator and its properties. The Hansen-Hurwitz estimator and its properties. Selection of samples with probability proportional to size (PPS) with replacement-use, application, estimate and standard error.

Sampling of unequal clusters with unequal probability without replacement –different selection methods: Brewer's, Durbin's, Sampford'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.

Multistage sampling: reasons for adopting this technique, two and three stage sampling schemes. Two-stage sampling with equal and unequal sized clusters - estimates and standard errors. Estimation for proportions. Optimum sampling fractions and sub-sampling fractions. Stratified two-stage sampling, Concept of self-weighting estimates, assumption required for self-weighting estimates, self-weighting techniques in multistage sampling.

Multiphase **sampling**: reasons for adopting this technique. Different estimators for double sampling and their respective standard errors.

Variance estimation in complex surveys: Complex surveys, Nonlinear estimation in complex surveys, linearization (Taylor series) methods, random group methods, re-sampling and replication methods, generalized variance functions, confidence intervals.

Repeated sampling: Basic features of some large scale sample surveys in Bangladesh: Bangladesh Demographic and Health Surveys (BDHS), Bangladesh Maternal Mortality and Maternal Health Survey (BMMS),BBS surveys.

Assignments:
Problems and exercises on the topics covered by the above syllabus of Sampling Techniques II and others (if necessary).

Texts:

1. Lohr, S.L. (2005), *Sampling: Design and Analysis*
2. Islam, M.N. (2008), *An Introduction to Sampling Methods*, Book World.

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References

1. Cochran, W.G, Sampling Techniques
2. Levy, P.S. and Lemeshow, S., Sampling of Populations.
3. Kish, L., Survey Sampling
4. Singh, D. & Chaudhury, F.S., Theory and Analysis of Sample Survey design.
5. Menddelhall, Ott, and Scaeffer, Elementary Survey Sampling.
6. Sukhatme, P.V. Sampling theory of Surveys with Application, 2nd ed. Asia Publishing House, London.

Stat-304: Regression Analysis **4 Credits**

Fitting a straight line by Least Squares : Straight line relationship between two variables, fitting a straight line, the analysis of variance, confidence intervals and tests for β_0 and β_1, F test for significance of regression.

Checking the straight line fit: Lack of fit and pure error, testing homogeneity of pure error, examining residuals : the basic plots, non-normality checks of residuls, checks for time effects, non-constant variance, need for transformation and curvature, other residual plots, Durbin-Watson test.

Regression in Matrix terms (Single covariate case): Fitting a straight line, Singularity; properties of estimators and fitted values, the analysis of variance.

The General Regression Situation: General linear regression, least square properties, analysis of variance, confidence intervals.

Extra Sums of squares and Tests: The "extra sum of squares" principle, partial and sequential F tests for two predictors.

Serial correlation in residuals and the Durbin-Watson Test : Serial correlations in residuals, the Durbin-Watson test, Run test.

More on checking fitted models: The hat matrix H and the various types of residuals , detection of influential observations : Cook's statistics, other statistics measuring influence.

Multiple regression- special topics: Generalized least squares and weighted least squares.

Polynomial regression fitting.

Transformation of the response variable : Introduction and preliminary remarks, power family of transformations on the response, Box-Cox method, transformations chosen to stabilize variance.

Indicator/Dummy variable : Indicator variables versus regression on allocated codes, dummy variables to separate blocks of data with different intercepts same model, interaction terms involving dummy variables, dummy variables for segmented models.

Selecting the "Best" regression equation : All possible regressions and "best subset" regression, stepwise regression, backward elimination, significance levels for selection procedures.

Ridge regression : Introduction, basic form of ridge regression, circumstances when ridge regression is absolutely the correct way to proceed , use of ridge regression in model selection.

Orthogonal polynomials and summary data: Introduction, orthogonal polynomials, regression analysis of summary data.

Text:

1. Draper, N.R. and Smith , H. (1998) : *Applied linear regression* (3rd edition) , Wiley, N.Y.

References:

1. Neter, J., Wasserman, W. and Kutner, M.: Applied linear regression models.
2. Ryan, T. P.(1997) : Modern Regression Methods , Wiley, N.Y.
3. Graybill, P.: An introduction to linear statistical models, Vol. 1 Mcgraw-hill, N.Y.
4. Montgomery, D.C. and Peck, E.: An introduction to Regression analysis,Wiley, N.y.

Stat H-305: Categorical Data Analysis **2 credits**

Contingency tables and chi-square test, McNemar's and Gart's test for 2×2 tables, Combining information from several 2×2 table, r×c contingency tables, Isolation of sources of association in r×c tables, Measure of association for contingency tables, Partitioning the degrees of freedom in contingency table, Combining and comparing results from different investigation, Relative measure of association: Lambda measure, Gamma measure and Sources D-measure.

Multidimensional tables: Analysis and test of hypothesis of 3-dimensional table, Stratified analysis, Confounding and interaction, Mantel-Haenszel test.

Log-linear models: Fitting log-linear models and estimating parameters, Contingency table with ordered categories.

Text

1. Agresti, A., Analysis of Ordinal Categorical Data.Wiley .N.Y.
2. Everitt, B.S., The Analysis of Contingency Tables, John Willey, N.Y.

Reference:

1. Habermen, Analysis of Frequence Data, University of Chicago.
2. Bi,hop, Y.M.M., Fienberg, S.E. and Holland, P.W (1975), Discrete Multivariate Analysis. Theory and Practice. MIT Press, Cambridge Massachusetts.
3. Cox, D.R., The Analysis of Binary Data Methuen.
4. Plakett, R.L., Analysis of Categrical Data.
5. Maxwell, A.E., Analyzing Quantitative Data.

Stat H-306: Epidemiology **4 credits**

Epidemiologic Concepts: Definition and Scope of Epidemiology, Key Issues in Epidemiology; Health and Disease; Sources of Data on Community Health, Vital Statistics and Morbidity Data; Descriptive Epidemiology: Person, Place, Time: Analytic Epidemiology: Causality.

Types of Epidemiologic Research: Experimental (Laboratory, Clinical Trial, Community Intervention), Quasi Experimental (Clinical/Laboratory, Program/Policy), Observational Studies: design options in observational studies – methods of observations; typology of observational study designs (Cohort, Case-Control, Cross-sectional Studies).

Measures of Disease **Frequency**: Incidence and Prevalence; Basic measures of Incidence and Prevalence, Mortality Measures, Age, Period and Cohort Effects.

Measures of **Association:** Ratio Measures and Difference Measures (Relative Risk, Odds Ratio; Risk Difference etc.), Comparison of Proportions from Different Samples, Standard Error of Estimators, Test of Hypotheses.

Measures of Potential Impact: Etiologic Fractions, Prevented Fractions.

Diagnostic Testing: Positive and Negative Predictive Values, False Positive and False Negative, Sensitivity and Specificity.

Validity: Validity and Precision, Direction of Bias, Sources of Bias, Selection Bias, Information Bias, Misclassification Bias.

Stratified Analysis: Test for Overall Association, Mantel-Haenszel Estimator and Test, Confounding, Criteria and Test for Confounding (Single Factor Confounding).

Matching: Definition of Matching, Types of Matching Schemes, R-to-1 Matching, Comparison of m Matched Samples, McNemar Test.

Interaction, Effect Modification and Synergism: Statistical Interaction and Effect Modification, Additive and Multiplicative models, Interaction assessment via regression analysis.

Text

1. Kleinbaum et al. (1982), *Epidemiologic Research: Principles and Quantitative Methods*, Von Nostrand, NewYork.
2. Jewel, N.P. (2004). *Statistics for Epidemiology*, Chapman & Hall/Crc.

References

1. Kahn, H.A. and Sempos, C.T. (1989). Statistical Methods in Epidemiology (Monographs in Epidemiology and Biostatistics, Vol. 12) (Paperback), Oxford University Press, New York.

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2. Rothman, K.J. and Greenland, S. (eds,) (1998). Modern Epidemiology, Lippincot-Raven, Philadelphia.
3. Fleiss, J.L. (1981). Statistical Methods for Rates and Proportions, 2nd Ed. Wiley, New York. Greenberg, R.S. et. al.

Stat H-307: Mathematical Demography & Actuarial Statistics 3 credits

Errors in demographic data: Types and sources of errors in demographic data, methods of evaluation and detection of errors in demographic data, graduation of data, Dual record system, census coverage and method of checking completeness of coverage.

Standardization of demographic measures: Direct and indirect method of standardization.

Life table: Definition, use and functions of life tables, different types of life table, construction of life tables. Actuarial life table, its construction and application. Force of mortality and related problems.

Population Models: Stable, quasi-stable and stationary population model. Fertility, mortality and ag3 structure in stable populations. Lotka and Dublen's model.

Nuptiality: Nuptiality models, Nuptiality table, Nuptiality pattern in Bangladesh.

Population Projection: Population estimates and projections. Mathematical methods, component method of population projection.

Actuarial Statistics:The meaning of Actuarial Science; role of insurance in the economy; role of an actuary.

Economics of insurance: utility theory, insurance and utility, elements of insurance, optimal insurance.

Individual short-term risk models: models for individual claims, approximations for the distributions of sum of claims, applications to insurance.

Texts

1. Shryock, H.S:, Siegel, J.S. et al., *The Methods and Materials of Demography.*
2. Andrew Hinde. *Demographic methods*
3. Barcley, G.W., *Techniques of Population Analysis.*
4. Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J. (1997), *Actuarial Mathematics*, 2nd Ed.
5. Kellison, S.G. (1991), *The Theory of Interests*, 2nd Ed.

References

1. Specigelman, *Introduction to Demography.*
2. Pollard, A.H., Farhat, Y. & Pollard, G.N., *Demographic Technique.*
3. Namboodiri, M.K. & Suchindran, C.M. (1987), *Life Table Techniques and their Applications*, Academic Press, London.
4. Kpedekpo, G.M.K., *Estimates of Demographic Analysis for Africa.*
5. Chiang, C. L., *The Life Table and its Application.*
6. *United Nations: Manuals I to XI.*
7. Bathen, R.W. (1978). *Mortality Table Construction.*
8. Biswas, S., *Stochastic Process in Demography and Application*, Wiley Eastern Ltd.
9. Journals: *Population Studies, Demography, Population and Development Review, Studies in Family Planning, Asia-Pacific Population Journal.*

Stat H-308: ANOVA and Linear Inference **3 credits**

Basic concepts of ANOVA: Variation in statistical data, causes of such variation (assignable and non-assignable), factors, levels, treatment, treatment combination, plot, block, yield or response, etc. Their definitions with examples.

Definition of ANOVA, importance and uses, basic assumptions of ANOVA, related concepts of experimental design & sample design, experimental error & sample error, etc.

ANOVA Techniques: Single-factor ANOVA, Double-factor ANOVA, Triple-factor ANOVA, etc. Partitioning of Total SS, D.F., Justification ANOVA-F test, ANOVA Table, Least Significance Difference (LSD),Grouping of treatments etc.

Hierarchical Classification: Cross & nested classifications, distinction, examples, 2-stage nested classification, models, parameter estimation, ANOVA techniques for both equal and unequal cases.

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Linear Inference: Linear estimation and testing of hypotheses, Statistical linear model, types of such model (Regression, ANOVA, ANCOVA, etc.). Types of ANOVA model: fixed, random, mixed models with illustrative examples and their uses in ANOVA techniques.

Variance-Component Analysis: Problems of random effect models having interactions, Satterthwaite approximate F-test, uses of such test in higher-way variance component models, mixed model etc. Problems of analysis of multi-way cross classifications.

ANOVA Theorem: Gauss-Markov set up, Cochran's Theorem with proof, estimable function, General linear hypothesis, testable hypothesis, non-testability, different versions of Gauss-Markov theorem, General theorem of ANOVA and its application (Non-full rank cases only).

Texts

1. Scheffe, H., *Analysis of Variance*, Wiley.
2. Searle-S.R., *Linear Models*, Wiley.
3. Hitson,A(1995): The Analysis of Variance, 3rd ed. Wiley, N. Y.

References

1. Montgomery, D.C., *Design & Analysis of Experimentals*, 2nd Ed., Wiley.
2. Seber, G.A.F., *General Linear Regression Analysis,* Wiley, N.Y.
3. Rao, C.R. & Mitra, *Generalised Inverses & its Applications*, Wiley.
4. Bhuyan, K.C., *Parrikkhar Naksha O Bishlasion.* Vol. I.
5. Snedecor, *G.W., Statistical Methods*, 1oth Ed., Prentice Hall of India.
6. Rao, C.R., *Analysis of Variance Components*, Elsevier-North Holand, N.Y.
7. Bhyiyan, M.R., *Fundamentals of Experimental Design.*
8. Sen, K., *Some Contributions to HANOVA*, Ph.D. Thesis.

Stat H-309: Mathematical Analysis **3 credits**

The real number system; axioms and completeness and its consequences; Dedekind cut, sets, compact sets; simple operations 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. Distinction between probability measure and Lebesque measure and Lebesque integrals.

Examples of applications in Statistics.

Text:

1. Rudin, W. (1976). Principles of Mathematical Analysis. McGraw-Hill.
2. Simmons, G.F,, Introduction to Topology & Modern Analysis, McGraw-Hill,N.Y.
3. Berherion S.K., Introduction to Measure & Integration.

References:

1. Royden, H.L., Real Analysis, Mcmillan,N.Y.
2. Schaum Series, Advanced Calculus & Real Analysis.
3. Sipschute, S., General Topol;ogy, McGraw-Hill, N.Y.
4. Halmos,P.R., Measure Theory, Van Nostrand, N. Y.
5. Billingeley, P., Probabability and Measure, Wiley, N.Y.
6. Kingman, J.F.G., Measure and Probability, CUP.
7. Pitt, H.R., Integration measure and Probability, Oliver and Boyed.
8. William, F.T.(2011): *Introduction to Real Analysis, Peason Publication, USA.*

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Stat H-310: Statistical Computing VI: Introduction to SPSS and Stata **2 credits**

Introduction to SPSS: Meaning, Application and Background of SPSS; Reading the Data set: Reading SPSS Data, Reading Data from Spreadsheet formats, Reading Data from Simple Data base formats, Reading Data from other Statistical Programs, e,g, STATA, SAS, etc; Defining the Variable: Variable type, Variable name, Variable formats, Variable Labels, Value Labels; Transformation Expressions: Numeric Expressions, Arithmetic Operations, Numeric Functions, Arithmetic Functions, Statistical Functions, Random Variable and Distribution Functions, Missing Values in Numeric Expressions, Logical Expressions, Logical Functions, Relational Operators, NOT Logical Operator, AND and OR Logical Operators, Other Functions; Working with Date and Time: Date and Time formats, Arithmetic operations with date and time variables, Date and Time functions; Working with Commands: Introduction, Syntax Diagrams, Command Specification, Running Commands, Subcommands, Keywords, Delimiters, Command Order; Different commands in SPSS: Get, Save Out file, Split Files, Sort Cases, Add Files, Match Files, Import, Compute, Recode, If, Select If, Do If, End If, List, Aggregate, Sample selection.

Introduction to STATA: An example of STATA, documentation and help files, searching for information; example commands, aerating a new data set, specifying subjects of data with in and if qualifiers, generating and replacing variables, using functions, converting numeric and string formats, creating new categorical and ordinal variables, importing data from other programs, combining STATA files, transporting, reshaping or collapsing data, weighting observations, creating random data and random samples, menaging memory.

Texts:

1. Norusis, MJ (1988). SPSS/PC for the IBM PC/XT/AT.
2. Hamilton, L. C. (2006), Statistics with STATA, Thomson Brooks/Cole.
3. Rabe-Hesketh, S and Everitt, BS (2007). A handbook of statistical analysis using stata, 4th edition, Chapman Hall/CRC.

Stat H-311 Statistical Computing VII: Demography, ANOVA and Regression (Using SPSS and STATA) **2 Credits**

Demography: Age-sex composition, population payramid, population growth rate, calculation of various rates and ratios of fertility, mortality, nuptiality, migration, standardization.of rates and ratios. Construction of life tables, etc.

ANOVA: Analysis of Variance (ANOVA) : One-way, two-way, Three-way classifications, Nested classifications, Analysis with multiple observations per cell, Tukey's test, t-test, multiple range test, F test, etc. Least significant difference (LSD).

Regression Analysis: Estimation of parameters of multiple regression model, Inference in multiple regression model (Test of significance of the overall regression, Testing general1.inear hypothesis. Test and confidence interval for indivsdual parameters). Partial correlation. Multiple correlation and related test, Model selection, Fitting polynomial regression, Orthogonal polynomials, Splines etc. Examination of residual, Outliers, Influence curve analysis.

Stat H-312: Oral Presentation 2 Credits

Fourth Year B.S. (Hons.)

Stat H-401: Multivariate Analysis **3 credits**

Introduction: Ideas of multivariate data, applications of multivariate techniques.

Multivariate distributions: Multinomial distribution with properties, Multivariate normal distribution (MND) with propertie, derivation of multiple and partial correlation co-efficients, estimation of parameters, Wishart distribution, Hotelling T^2 distribution and Mahalanobis D^2, their properties, Generalised variance and its distribution.

Distribution of quadratic forms: Quadratic forms and their central and non-central distributions. Expectations and variances and co-variances of quadratic forms. Independence of two or more quadratic forms.

Inference about a Mean Vector: Introduction, test of a mean vector of normal population, Likelihood ratio tests, confidence regions and simultaneous comparisons of component means, large sample inferences about a population mean vector, inferences about mean vectors when some observations are missing.

Comparisons of Several Multivariate Means: Introduction, paired comparison and a repeated measures design, comparing mean vectors from two populations, comparing several multivariate population means (One-Way MANOVA), simultaneous confidence intervals for treatments effects, two-way multivariate analysis of variance, profile analysis, repeated measures designs and growth curves.

Multivariate Linear Regression Models: Introduction, the classical linear regression model, least squares estimation, inferences about the regression model, inferences from the estimated regression function, model checking, multivariate multiple regression.

Texts

1. Johnson, R.A. & Wichern, D.W. (1982), *Applied Multivariate Analysis*, Prentice- Hall Inc., Englewood Cliffs, NJ.
2. Anderson, T.W. (1984), *Introduction of Multivariate Statistical Analysis*, 2nd Ed., John Wiley.

References

1. Morrison, D.P. (1976), *Multivariate Statistical Methods*, McGraw-Hill.
2. Bhuiyan, K.C. (2006), Multivariate Analysis and its Applications.
3. Hosmer, D.W. and Lemeshow, S. (1989), *Applied Logistic Regression*, John Wiely & Sons.
4. Kleinbaum, D.G., Kupper and Muller, K.E. (1998), *Applied Regression Analysis and other Multivariate Methods*, 3rd Ed., Duxburg Press, Pacific Grove.
5. Maardia, K.V., Kent, S.T. and Bibly, J.M., *Multivariate Analysis*, Academic Press, London.
6. Johnson, N.L. and Kotz, S. (1969), *Continuous Multivariate Distributions*, John Wiley.
7. Kendall and Stuart, *Advance Theory of Statistics*, Vol. 1 and 3
8. Rao, C.R., *Linear Statistical Inference and its Applications*, Wiley, N.Y
9. K V Mardia, J T Kent and J Bibby, *Multivariate Analysis*, Academic Press, 1979.

Stat H-402: Introduction to Robust Statistics **3 credits**

Introduction: definition and aims of robust statistics, classical versus robust approaches to statistics.

Location and scale: robust location and dispersion estimates, M-estimates of location with known scale, M-estimates of scale, simultaneous M-estimates of location and scale, numerical computation of M-estimates.

Measuring robustness: influence function, breakdown point, maximum asymptotic bias; balancing robustness and efficiency.

Correlation and regression: robust correlation estimates, linear regression models with fixed predictors: regression M-estimates; models with random predictors: MM-estimate, LMS estimate, S-estimate, LTS estimate, tau-estimate.

Text

1. Maronna, R.A., Martin, R. D. and Yohai, V. J. (2006), *Robust Statistics: Theory and Methods*, John Wiley & Sons.

References

1. Hampel, F.R., Ronchetti, E.M., Rousseeuw, P.J. and Stahel, W.A. (1986), Robust Statistics: The Approach Based on Influence Functions, John Wiley & Sons.
2. Huber, P.J. (1981), Robust Statistics, John Wiley & Sons.

Stat H-403: Design and Analysis of Experiment **4 credits**

Basic concepts of Experiments and designing: Experiment and its types. Steps involved in experiment, Designing experiments, its purposes, Basic principles of experimental designs, their purposes, Fisher's diagram, etc.

Experimental Units: Definition, different types: agricultural plots, block, examples in other areas, Reasons of blocking, Uniformity trials and fertility control mapping, Choice of size and shape of plots and blocks, Smith's variance law and other field plot techniques.

Experimental error and sampling error, Sources of experimental error and controlling measures.

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Basic Experimental designs: Completely Randomised Design (CRD), Randomised Block Design (RBD), Latin Square Design (LSD), Gracco LSD. Multiple LSD, Nested design (ND), etc., their definitions and layouts, relative merits, demerits, orthogonality and relative efficiency, etc.

Multiple Comparison: Grouping of treatments, necessity, different methods: Fisher's least significant method, Duncan's multiple range test, Student-Newmen-Keul's test, Tukey's test, Scheffe's method, etc.

Missing plot techniques: Orthogonality and Non-orthogonality problems, effects of missing values in basic designs, methods of estimation for missing values, and their standard error, LS method, Iterative method etc. Adjustment in analysis procedures, Comparison of pair treatments in missing plots etc.

Factorial Experiments: Basic ideas of variety trials, factorial experiment, Bio-assays, etc. Linear contracts, orthogonal contrasts different factorial experiments: 2^k ,etc. simple-effects, main-effects & interactions and analysis procedures: Contrast method, Yates algorithm, Confounding in factorial experiments: Definitions, necessity, different types of confounding and their analysis, Asymmetric factorial experiments 2×3, 2×4, 3×4,etc.

Analysis of Covariance (ANCOVA): Concomitant variables, examples, definition of ANOVA with one concomitant variable in different basic designs: Their linear models, estimation of parameters, analysis procedures, related tests, etc.

Other Designs: (i) Non-orthogonal designs (unequal cases) (ii) Split-plot designs (iii) Switch-over designs (iv) Carry-over designs.

Texts

1. Montgomery,D.C. (2003), *Design and Analysis of Experiments*, 5th Ed.,Wiley, N.Y.
2. M.R. Bhuiyan (2007), *Fundamentals of Experimental Design,* 2nd Ed.

References

1. Cochran & Cox (1952), *Experimental Design*, Wiley, N.Y.
2. Kempthrone, *Design and Analysis of Experiments*, Wiley, N.Y.
3. Yates, F., *Design and Analysis of Factorial Experiments*, Harpenden, Herts, England.
4. Searle, S.R., *Linear Models.*
5. John, U.A. & Quenouille, M.H., *Design & Analysis of Experiments*, Charles Griffin & Co., London.
6. Steel and Torrie (1982), *Principle and Procedures of Statistics.*
7. Cox, D.R., *Planning of Experiments.*
8. K.C. Bhuiyan, *Experiemntal Design and Analysis of Variance*, Vol.1 & 2, Bangla Academy.
9. Das, M.N. and Giri, N.C., *Design and Analysis of Experiments.*

Stat H-404: Econometrics **3 Credits**

Concepts: meaning, definition, scope and role of econometrics, difference with mathematical economics and economic statistics, nature and scope of data for econometric analysis.

Measures of Model Adequacy: Residual analysis, Outlier analysis and choice of regressors.

Model Misspecification: Basic concepts and consequences, Omitted variables, Irrelevant variables and Measurement errors.

Regression with Qualitative dependent variable: Introduction to linear probability model. Logit, Probit and Tobit model.

Generalized least squares (GLS): Spherical and nonspherical disturbances, sources of nonspherical disturbances and problems associated with these, OLS estimators under nonsplierical disturbances and their properties, the Generalized Least-Squares estimator.

Multicollinearity: Basic concepts, reasons, consequences, detection and remedial measures.

Autocorrelation: Basic concepts, reasons, consequences, detection and remedial measures.

Heteroscedasticity: Basic concepts, reasons, consequences, detection and remedial measures.

Simultaneous equation models: Basic concepts; endogenous, exogenous and predetermined variables, structural model and reduced-form model; simultaneous equation bias, inconsistency of OLS estimators.
Estimation of simultaneous equation models: method of indirect least-squares (ILS) and two-stage least-squares (2SLS).
Identification: Concept of identification and methods of identification.

Nonlinear Regression Models: Estimation of linear and nonlinear regression models, different approaches to estimating nonlinear regression models, properties of nonlinear regression, The Cobb-Douglas and CES production function, estimation of Cobb-Douglas production function.

Dummy variable regression models: Basic concepts, ANOVA models, caution in the use of dummy variables, ANOVA models with two qualitative variables, regression with a combination of quantitative and qualitative regressors. The ANCOVA models, testing the structural stability of regression model and comparing two regression by dummy variable, comparison with chow test, use of dummy variables

Time Series Econometrics: Basic concepts, Cointegration. Spurious regression. Forecasting approaches in econometrics.

Texts

1. Gujarati. D.N., *Basic Econometrics*.
2. Draper, N.R, and Smith, H. (1998), *Applied Linear Regression*, 3rd edition, Wiley, N.Y.

References

1. Wallis, K.F., *Applied Econometrics*.
2. Dhrymes, P.J, *Econometrics*, Springer-Verlg, N.Y.
3. Goldberger, A.S., *Econometric Theory*, Wiley & Sons, N.Y.
4. Johnston, J., *Econometrics Methods*, 3rd Ed., McGraw-Hill, N.Y.
5. Griffiths, J., *The Theory and Practice of Econometrics*, Wiley & Sons, N.Y.
6. Malinvaud, E., *Statistical Methods of Econometrics*, 3rd Ed., North Holland.
7. Theil, H., *Principles of Econometrics*, North Holland.
8. Christ, C.F., *Econometric Models and Methods*.

Stat H-405: Biostatistics **4 credits**

Biostatistics, Survival Analysis, Survival Data, Examples of Survival Data.

Basic Concepts of Lifetime Distributions: Probability Distribution Function, Hazard Function, Survival Function, Interrelationships, Mean Residual Life Function and Quantile Lifetime, Empirical survival Function, Product Limit Approach for the Estimation of Survival Function for Complete Lifetime Data, Survival Curves, Hazard Curves.

Important Lifetime Distributions: Exponential, Weibull, Extreme Value, Log-normal, Normal, Log-logistic, Logistics, Location-scale, Log-location-scale. Goodness of fit: Graphical Approach. Survival Function, Hazard Function, Mean Residual Life Function, Quantile under Different Lifetime Distributions.

Estimation and Test: Maximum Likelihood Function, Properties of Maximum Likelihood Estimators, Newton-Raphson Iterative approach, Wald Test, Score Test, Likelihood Ratio Test.

Incomplete Data: Censoring, Left and Right Censoring, Type I (Progressive Type I, Generalized Type I etc.), Type II Censoring, Progressive Type II Censoring, Random Censoring, Construction of Likelihood Functions under Different censoring Schemes.

Parametric Methods: Estimation and Tests (for small and large samples) under Different Censoring schemes for Important Lifetime Distributions, Confidence Intervals, Delta Method, Estimation, Test, and Confidence Interval for Survival Function, Hazard Function, Quantile

Non-parametric Methods: Estimation of Hazard and Survival Functions, Product-Limit Methods, Standard Errors, Median Survival Time, Tests, Confidence Intervals.

Comparison of Survival Curves: Comparison of Two Groups: Log-rank (Mantel-Haenszel) Test; Other Tests Comparing Two Groups, Comparison of More than Two Groups.

Logistic Regression Model: Introduction to Logistic Regression, Importance of Logistic Regression Model, Regression Model, Computing the Odds Ratio in Logistic Regression, Maximum Likelihood Estimation, Statistical Inferences, Polytomous Logistic Regression Model.

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Texts

1. Lawless, J.F. 2003. Statistical Models and Methods for Lifetime Data (2nd Edition). Wiley, New York.

Reference:

1. Kalbfleisch, J.D. and Prentice, R.L. (2002), *The Statistical Analysis of Failure Time Data.* Wiley, NewYork.
2. Hosmer, D.W. and Lemeshow, S. (2000), *Applied Logistic Regression* (2nd Edition). Wiley, New York. Klein, J.P. and Moeschberger, M.L. *Survival Analysis* (2nd Edition). Springer, New York.
3. Cox, D.R. and Oakes, D. (1988), *Analysis of Survival Data*, Chapman and Hall, London.
4. Kleinbaum, D.G. (1994), *Logistic Regression*, Springer-Verlag, New York.
5. Kleinbaum, D.G. (1996), *Survival Analysis*, Springer, New York.
6. Breslow, N.E. and Day, N.E. (1980), Statistical Cancer Research I: The Analysis of Case- control Studies, IARC, Lyon.
7. Beeker, N.G. (1987), *Analysis of Infectious Disease Data*, Chapman and Hall: London.
8. Parmar, M.K.B. and Machin, D., *Survival Analysis.*
9. Lee, E.T. (1980), *Statistical Method for Survival Data Analysis*, Life Learning Publication, Belmont, California.

Stat H-406: Introduction to Artificial Intelligence **3 credits**

Introduction - What is Artificial intelligence (AI), Application of AI, Philosophy of AI, AI research: problem of AI and approaches to AI.

Intelligent Agents - Agents and environments, Good behavior of the agents, Performance measures, The nature of environments, structure of agents – Simple reflex agents, Model based reflex agents, Goal based agents, Utility based agents.

Problem solving - problem solving agents, formulating problem, measuring problem solving performance, uniformed search strategies: Breadth-first search, Uniform-cost search, Depth-first search, Depth limited search, Iterative deepening depth- first search, Bidirectional search, Comparing uninformed search strategies.

Knowledge representation - Knowledge based agents, prepositional logic, Syntax and semantics, Equivalence, Validity and Satisfiability, Resolution, Conjunctive normal form (CNF)

First order logic - representation revisited, Syntax and semantics for first order logic, Using first order logic, prepositional versus first order logic.

Uncertain knowledge and reasoning - Handling uncertain knowledge (using knowledge of probability), inference using full joint distribution, independence, Bayes' rules and its use (simple case and combining evidence).

Probabilistic reasoning - Bayesian network, method for constructing Bayesian networks, conditional independence relations in Bayesian networks, Bayesian nets with continuous variables, Naïve Bayes models.

Text

1. Russell, S. and Norvig, P. (2004), *Artificial Intelligence – A Modern Approach*, 2nd Edition, Pearson Education / Prentice Hall of India.

References

1. Nilsson, N.J. (2000), *Artificial Intelligence: A new Synthesis*, Harcourt Asia Pvt. Ltd.
2. Rich, E. and Knight, K. (2003), *Artificial Intelligence*, 2nd Edition, Tata McGraw-Hill.

Stat H-407: Research Methodology **3 credits**

Research and methods: meaning of research, concepts of methods and methodologies, selection of topic, research process, categories of research: descriptive, exploratory and explanatory; conceptualization, operationalization, formulation of research proposal, review of literature, objectives of the study, concepts of reliability and validity.

Research Design: types of design -- case studies, trend and panel studies, experimental design, non-experimental design, cross-sectional and quasi-experimental design, etc.

Sampling design and sample size determination.

Data collection methods and techniques: primary and secondary sources of data, different methods to collect data: mail-questionnaire, personal interview, telephone interview, principles of interviewing.

Qualitative data collection: observations, key informants interview, in-depth interview, focus group discussion (FGD), rapid appraisal technique (RAT), Delphi technique.

Measurement of reliability: classical theory of reliability, reliability coefficient, extension of classical theory, test-retest method, parallel forms technique, split-half method.

Measurement of validity: content validity, empirical validity, construct validity, validity threats.

Data processing , analysis and Report writing.

Proposal Writing.

Text

1. Bailey, *Social Research Methods*.
2. Islam, M.N. (2011), *An introduction to Research Methods*, Book World.
3. Neuman, W.L. (2000), *Social Research Methods: Qualitative and Quantitative Approaches*, Fourth Edition, Allyn and Bacon, Boston.

References

1. Frankfort, J., *Research Methodology.*
2. Kothari, C.R., *Research Methodology.*
3. Krisaaswami and Raaganatham, *Methodology of research in social sciences.*
4. Das, A. *Social survey and research.*
5. Sufian, A.J.M., *Methods and techniques of social research.*
6. Rao, C.R, *Applied Statistical Methods in Biometric Research.*
7. Palmor, J.O., *Statistical Methods in Research.*
8. Kish, L., *Survey Methods in Social Investigation.*

Stat H-408: Stochastic Processes **3 Credits**

Concept of Stochastic process, Different types of stochastic process, Markov Process. Transition Matrix, Higher Transition probabilities, Chapman-Kolmogorov equation, Recurrent events, Transient states, Classification of states, Ergodic properties, Evaluation of P^n.

Gambler's Ruin Problem, Random Walk Model.

Markov Process, Discrete Time Markov Chains, Continuous Time Markov Chains

Homogeneous Markov Process: Counting Process, Poisson Process, Birth Process Death Process, Birth Death Process.

Queuing Process: Concepts, components of Queuing process, Queuing model, Single server queues, Multiple server queues, Equilibrium theory, limiting properties of queues, related mathematical problems.

Texts

1. Karlin, S. & Taylor, H.M., *A first Course in Stochastic Processes*, 2nd Ed., Academic Press.
2. Medhi, *Stochastic Process*, Wiley Eastern Ltd.

References

1. Kulkarni, V.G., (1995), *Modelling and Analysis of Stochastic Systems*, Chapman and Hall
2. Gross, D. and Harris, C.M. (1976), *Fundamentals of Queueing Theory*, John Wiley.
3. Bhat, B,R., *Modern Probability Theory*, Wiley Eastern Ltd.
4. Ross, S.M. *Stochastic Process.*
5. Bartlett, M.S., *Introduction to Stochastic Process.*
6. Cinlar, E. (1975), *Introduction to Stochastic Processes*, Prentice-Hall.
7. Kanan, D. *An Introduction to Stochastic Processes.*
8. Isaacson, D.L. and Madsen, R.W. Markov Chains: *Theory and Applications.*
9. Ross, S.M. (2004), *Introduction to Probability Models*, Academic Press.

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Stat H-409: Time Series Analysis **4 Credits**

Fundamental concepts: Stochastic processes, the autocovariance and autocorrelation function (ACF), the partial autocorrelation function (PACF), sample mean, sample autocovariance , sample ACF, sample PACF, moving average (MA) and autoregressive (AR) representation of time series processes, linear difference equation.

Stationary time series models: Autoregressive processes: 1st order autoregressive AR(1) process, 2nd order autoregressive AR(2) process, the general p-th order autoregressive AR(p) process.

Moving average processes: 1st order moving average MA(1) process, 2nd order moving average MA(2) process, the general q-th order moving average MA (q) process. The dual relationship between AR(p) and MA(q) processes. The general autoregressive moving average ARMA(p,q) process, the ARMA(1,1) process.

Nonstationary time series models: Nonstationarity in the mean: Deterministic trend models, Stochastic trend models and differencing. Autoregressive integrated moving average (ARIMA) models: The general ARIMA model, the random walk model, the ARIMA(0,1,1) or IMA(1,1) model. Nonstationarity in the variance and the autocovariance: Variance and autocovariance of the ARIMA models, Variance stabilizing transformations.

Forecasting: Minimum mean square error (MSE) forecasts: Minimum MSE forecasts for ARMA models, Minimum MSE forecasts for ARIMA models, Computation of forecasts.

Model identification: Steps for model identification.

Parameter estimation, Diagnostic checking and Model selection: Parameter estimation for AR(1) and MA(1), Diagnostic checking, Model selection criteria.

Seasonal time series models: Traditional methods (Regression method, Moving average method) Seasonal ARIMA models.

Testing for a unit root: Testing for a unit root in the AR(1) model, testing for a unit root in a more general model, testing for a unit root in seasonal time series models.

Texts:
1. Time Series Analysis- Univariate and Multivariate Methods (2nd Edition) William W.S. Wei, Pearson Education Inc.

References:
1. Time Series Analysis Forecasting and Control (4th Edition)
2. George E.P. Box, Gwilym M. Jenkins & Gregory C. Reinsel, Wiley
3. Time Series Analysis and Its Applications With R Examples (3rd Edition) Robert H. Shumway and David S. Stoffer, Springer
4. Time Series Analysis With Applications in R (2nd Edition) Jonathan D. Cryer and Kung-Sik Chan, Springer

Stat H-410: Comprehensive **2 Credits**

All courses from first year to third year.

Stat H-411: Statistical Computing VIII: Multivariate Analysis and Experimental Design (using R and Stata) 2 Credits

Experimental Design: Missing plots techniques, Relative efficiency, Split plot designs, Covariance Analysis, analysis of 2^n factorial experiments. Confounding, Different designs with more than one observation per cell. Analysis of nested designs, Covariance analysis, Analysis of different advanced designs.

Multivariable Analysis: Drawing samples from univariate and multivariate distributions. Inference of mean vector and variance-covariance matrix of multivariate population, Comparison of several multivariate means, Drawing power curves for different hupotheses.

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Stat H-412: Statistical Computing IX: Biostatistics and Robust Statistics (using R and Stata) **2 Credits**

Biostatistics: Fitting of Survival Distribution, Non-parametric Estimation of Survival and Hazard Functions, Standard Errors and Confidence Intervals, Comparison of two Survival Curves.

Robust Statistics: Robust location and dispersion estimates. Robust estimates for linear models. Robust confidence intervals and tests.

Stat H-413: Statistical Computing X: Econometrics and Time Series (using R and Stata) **2 Credits**

Econometrics: Test on model adequacy, fitting of regression, estimation of parameters in generalized linear model assuming the presence of autocorrelation and heteroscedasticity, test on heteroscedasticity and autocorrelation, test on multicollinearity (BKW procedure).
Time Series: Determination of components of time data, periodogram anlysis, Correlogram analysis, Demand analysis, Fitting of production Functions, Forecasting by fitted functions, Confidence intervals for predicted values.

Stat H-414: Oral Presentation **2 Credits**

The End

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