I SEMESTER

STA C 101

Mathematical Analysis and Linear Algebra

Full Marks: 100 **4 Credits**

Unit 1 Recap of elements of set theory, real numbers, n-dimensional Euclidian space, open and closed intervals (rectangles), compact sets. Bolzano - Weirstrass theorem, Heine - Borel theorem. Sequences and series of real numbers; their convergence. Real valued function, continuous function, uniform continuity. (12 Lectures)

Unit 2 Differentiation, maxima – minima of functions, functions of several variables, constrained maxima – minima of functions. Reimann integral, mean value theorem, improper integrals, multiple integrals and their evaluation. Differentiation and Integration under the sign of integral - Leibnitz rule. (12 Lectures)

Unit 3 Vectors and matrices, types of matrices, determinants and their properties. Orthogonal and idempotent matrices, linear dependence. Vector spaces over fields of scalars, subspaces, linear independence of vectors, basis and dimension of a vector space, completion theorem, orthogonality of vectors and subspaces, Vector spaces with an inner product, Gram-Schmidt orthogonalization process, orthonormal basis, linear transformations and projections. (12 Lectures)

Unit 4 Non-singular matrices and their inversion, ranks, row and column rank of a matrix, partitioned matrices, G - inverse, Kronecker product. Systems of homogeneous and non-homogeneous linear equations, their consistency and maximal linearly independent solutions, minimal and characteristic polynomials of a square matrix, Characteristic roots and vectors and their extraction, similarity and diagonalization of square matrices. Real quadratic forms and their value classes, canonical reductions and simultaneous reducibility of quadratic forms. (12 Lectures)

Text Books

1. Bartle, R.G. (1976). Elements of Real Analysis, John Wiley & Sons, New York.
2. Narayan, S. (1993). Mathematical Analysis, S. Chand and Co., New Delhi.
3. Rudin, W. (1976). Principles of Mathematical Analysis, 3rd edition, McGraw-Hill, New York.
4. Fieller, N.(2016). Basics of Matrix Algebra for Statistics with R, CRC.
5. Hadley, G. (1987). Linear Algebra, Narosa Publishing House, New Delhi.
6. Lay, David C. (1997). Linear Algebra and its Applications, Addison-Wesley,
7. Singh, B.M. (2008). Introductory Linear Algebra, South Asian Publishers Pvt. Ltd., New Delhi.
8. Searle, S.R. (1982). Matrix Algebra useful for Statistics, John Wiley & Sons, New York.
9. Kolman, B. and Hill, D. R. (2010). Elementary Linear Algebra with Applications, 10TH Ed., Pearson.

Additional References

1. Apostol, T.M. (1985). Mathematical Analysis, Narosa Publishing House, New Delhi.
2. Golub, Gene H and Loan C.F. Van (1996). Matrix Computations (John Hopkins Studies in Mathematical Science) 3rd Edition, John Hopkins University Press, USA.
3. Gentle, James E. (2005). Matrix Algebra: Theory, Computations and Applications in Statistics, Springer Text in Statistics, Springer-Verlag, New York.
4. Banerjee, S. and Roy, A.(2014). Linear Algebra and Matrix Analysis, CRC
5. Rao, A.R. and Bhimasankaram, P. (1992). Linear Algebra, Tata McGraw-Hill, New Delhi
6. Rao, C.R. (1995). Linear Statistical Inference and its Applications, Wiley Eastern, New Delhi.

STA C 102

Distribution Theory

Full Marks: 100 **4 Credits**

Unit 1 Joint, marginal and conditional distributions. Computations of probability, expectations and variances by conditioning, generating functions (m.g.f and p.g.f) of random variables, Bivariate and Multivariate p.g.f, their properties and applications. Some continuous distributions (Exponential, Gamma, Beta, Cauchy, Pareto, Weibull, lognormal), Bivariate normal and bivariate exponential distributions and their properties, multinomial distribution.

(12 Lectures)

Unit 2 Functions of random variables and their distributions using Jacobian and other tools, convolution and compound distributions; idea of truncated and mixture distributions; concept of weighted distribution and length biased distributions; sampling distributions from normal population, central and non - central Chi-square, t- and F-distributions.

(12 Lectures)

Unit 3 Order statistics and their distributions and properties. Joint, marginal and conditional distributions of order statistics. Pdf of sample median, range, quasi range, moments and recurrence relations, modal equations. Extreme values and their asymptotic distribution (statement only) with applications, Asymptotic distribution of median, distribution of quantiles.

(12 Lectures)

Unit 4 Multivariate normal distribution, p.d.f and c.d.f moments, marginal and conditional distributions. Properties of Multivariate Normal distribution. Multiple and Partial correlation.

(12 Lectures)

Text Books

1. Hogg, R.V. and Craig, A.L. (1978). Introduction to Mathematical Statistics, McMillan, New York.
2. Mood, A.M., Grabyl, F.A. and Boes, D.C. (2001). Introduction to Theory of Statistics, Tata McGraw Hill, New Delhi.
3. Ross, S. M. (2004) Introduction to Probability and Statistics for Engineers and Scientist, Third Edition, Elsevier Academic Press, USA.
4. Rohatgi V.K. and Saleh, A.K.Md. E. (2001). An Introduction to Probability and Statistics (Second Edition), John Wiley and Sons (Asia), Singapore.
5. Singh, B.M.(2002). Multivariate Statistical Analysis. South Asian Publishers Pvt. Ltd., New Delhi.

Additional References

1. Dudewicz, E.J. and Mishra, S.N. (1988). Modern Mathematical Statistics, John Wiley, New York.
2. Johnson, S and Kotz, S. (1970). Continuous univariate Distributions I and II John Wiley, New York..
3. Pitman, J. (1993). Probability, Narosa Publishing House, New Delhi.
4. David, W.S.(2003). Order Statistics. (Second Edition). John Wiley and Sons, New York.
5. Ferguson, T.S. (1996). A Course on Large Sample Theory. Chapman and Hall, London.
6. Johnson, N.L. and Kotz, S.(1970). Continuous Univariate Distributions – 2, John Wiley and Sons, New York.

STA C 103

Probability Theory

Full Marks: 100 **4 Credits**

Unit 1 Classes of sets, fields, sigma-fields, minimal sigma-field, Borel sigma-field in R^k, sequence of sets, limsup and liminf of a sequence of sets. Measure, Probability measure, properties of a measure, Caratheodory extension theorem (statement only). (12 Lectures)

Unit 2 Measurable functions as limit of simple functions, Random variables, sequence of random variables, almost sure convergence, convergence in probability (and in measure). Integration of a measurable function with respect to a measure. Expectation and moments. (statements of) Monotone convergence theorem, Fatou's lemma, and Dominated convergence theorem (and discussion). (12 Lectures)

Unit 3 Probability inequalities (Markov, Tchebyshef, Jensen), WLLN. Independence, Borel- Cantelli Lemma, Kolmogorov zero-one law and Borel zero-one law. Kolmogorov's Strong Law of Large numbers for iid sequences.

(12 Lectures)

Unit 4 Convergence in distribution, characteristic functions and their elementary properties, Inversion and Uniqueness theorem, Polya's theorem and Levy's continuity theorem (statement only), De Moivre-Laplace Central Limit Theorem (CLT), Lindeberg-Levy's CLT, Liapounov CLT and applications.

(12 Lectures)

Text Books

1. Parthasarthy, K. R. (1980). Introduction to Probability Theory and Measure. McMillan, India.
2. Ross, S.M. (2005). A First Course in Probability, 7th Edition, Prentice Hall, New Jersy.
3. Ross, S. M. and Erol, A. P. (2007): A Second Course in Probability, www. Probability Book Store. Com, Boston, USA.
4. Singh, B. M. (2002). Measure, Probability and Stochastic Processes, South Asian Publishers, New Delhi.
5. Ross, S. M. (2001), "Probability Models for Computer science", Academic Press.
6. Dudley, R. M. (2002), "Real Analysis and Probability", 2ND Ed., Cambridge.
7. Robert, B. A., Birnbaum, Z. W. and Lucacs, E. (1972), "Real Analysis and Probability", Academic Press.

Additional References

1. Billingsley, P. (1986). Probability and Measure. John Wiley & Sons, New York.
2. Feller, W. (1985). Introduction to Probability theory and its Applications.(Vol. 1&2). Wiley Eastern, New Delhi.
3. Kingman, J F C and Taylor, S. J. (1966). Introduction to Measure and Probability. Cambridge University Press.
4. Natarajan, A. M. and Tamilarasi. A. (2003). Probability, Random Process and Queuing Theory, New Age International Publishers, New Delhi.
5. Rao, C. R. (1995). Linear Statistical Inference and its Applications. Wiley Eastern, New Delhi.

STA C 104 (P)

Statistical Computing in R

Full Marks: 50 **2 Credits**

Section 1 Introduction to R environment, R as a calculator, data types and structures, simple manipulations of data, vectors and vector arithmetic, objects, their modes and attributes, ordered and unordered factors, arrays and matrices, lists and data frames, reading data from files. Basics of R syntax, subsetting, loops and conditional execution, writing R functions. R graphics and tables.

Section 2 Exploratory data analysis in R, statistical functions, probability distributions and simulations, statistical inference, contingency tables, chi-square goodness of fit, least squares, maximum likelihood, non-linear optimization, empirical distributions and resampling, linear models and advanced modeling methods.

Text Books

1. Dalgaard, P. (2000). Introductory Statistics with R, Springer.
2. Dennis, B. (2013). The R Student Companion, Taylor and Francis.
3. Crawley, M J. (2013). The R Book, John Wiley and Sons.

Additional references

1. Chambers, J. (2008). Software for Data Analysis: Programming with R, Springer.
2. Jones, O., Maillardet, R. and Robinson, A.(2009). Introduction to Scientific Programming and Simulation using R, CRC.
3. Everitt, B. and Hothorn, T.(2006). A Handbook of Statistical Analyses Using R, CRC.

STA C 105 (P)

Distribution and Linear Algebra

Full Marks: 100 **4 Credits**

Problems based on following topics:

Section A:

- Stem and Leaf, Box and Whisker's plots
- Empirical Distribution plots
- Fitting of some standard distributions; goodness of fit test, p-p and q-q plots
- Plotting of density and distribution functions for exponential family with varying location, scale, and shape parameters
- Model sampling from standard distributions
- Generating samples using probability integral transform/ Box-Muller transformation
- Sample generation from chi-square, t, F and lognormal distributions using standard normal variates; comparison of histogram of the generated data and the corresponding density plot
- Sampling from mixture distributions (normal and exponential) and drawing histograms
- Fitting of Pareto distribution
- Fitting of Weibull distribution
- Fitting of lognormal distribution
- Multiple and partial correlation

Section B:

- Determinant: pivotal consideration method
- Solutions of a system of linear equations: Gauss elimination method
- Matrix inversion – Gauss Jordon elimination method
- Computation of G – inverse
- Characteristic roots and vectors by power method/singular value decomposition
- Triangular reduction of a positive definite matrix
- QR decomposition of a non-singular matrix
- Spectral decomposition of a real symmetric matrix
- Canonical reduction of quadratic forms Solutions of a system of linear equations and least squares
- Matrix inversion and computation of G - inverse
- Eigen analysis of matrices
- Spectral decomposition of a real symmetric matrix
- Solution to non-linear equation Newton-Raplson/Steepest descent
- Univariate optimization using Fisher's scoring/iteratively reweighted least squares

Text Books

1. Dudewicz, E.J. and Mishra, S.N. (1988). Modern Mathematical Statistics, John Wiley, New York.
2. Goon, A.M., Gupta, M.K. and Disrupt, B. (2000). Fundamentals of Statistics, Vol. I, World Press, Collate.
3. Hogg, R.V. and Tanis, E.A. (2003). Probability and Statistical Inference, Pearson Education, Delhi.
4. Rohatgi V.K. and Saleh, A.K.Md. E. (2001). An Introduction to Probability and Statistics (Second Edition), John Wiley and Sons (Asia), Singapore.
5. Rao, A. R. and Bhimasankaran, P. (1992), Linear Algebra, Tata McGraw Hill, New Delhi.
6. Searle, S. R.(1982). Matrix Algebra useful for Statistics, John Wiley & Sons, Inc., New York.
7. Thisted, R. A. (1988). Elements of Statistical Computing. Chapman and Hall.
8. Dalgaard, P. (2000). Introductory Statistics with R, Springer.
9. Dennis, B. (2013). The R Student Companion, Taylor and Francis Golub Gene H. and Loan C.F. Van (1996). Matrix Computations (John Hopkins Studies in Mathematical Science) 3rd Edition; John Hopkins University Press, USA.
10. Fieller, N.(2016). Basics of Matrix Algebra for Statistics with R, CRC.
11. Gentle, James E (2005). Matrix Algebra: Theory, Computations and Applications in Statistics, Springer, New York.
12 Givens, G. H. and Hoefting, J. A. (2005). Computational Statistics, John Wiley & Sons, New York.

Reference Books

1. Wasserman, L. (2004). All of Statistics: A Concise Course in Statistical Inference, Springer Science Business Media, Inc., New York.
2. Golub Gene H. and Loan C.F. Van (1996). Matrix Computations (John Hopkins Studies in Mathematical Science) 3rd Edition;

John Hopkins University Press, USA.

II SEMESTER

STA C 201

Survey Sampling

Full Marks: 100 **4 Credits**

Unit 1 Simple random sampling WR & SRSWOR - estimation based on distinct units in SRSWR. systematic sampling (linear, circular, population with linear trend), domain estimation in SRS. Ratio and regression estimators based on double sampling and SRS. (12 Lectures)

Unit 2 Unequal probability sampling; pps wr and wor methods (including Lahiri's scheme) and related estimators of a finite population mean. Hansen – Hurwitz and Desraj estimators for a general sample size and Murthy's estimator for a sample of size 2. Horvitz – Thompson Estimator (HTE). (12 Lectures)

Unit 3 Stratified sampling, allocation problem and construction of strata; Cluster and Multi-stage sampling under stratification. (12 Lectures)

Unit 4 Double sampling. Non-sampling errors, modeling observational errors. Application to longitudinal studies. Randomized response technique: Warner's related question model, unrelated question model, small area estimation. (12 Lectures)

Text Books

1. Cochran, W.G. (1997). Sampling Techniques, Wiley Eastern, New Delhi.
2. Mukhopadhyay, P. (1998). Theory and Methods of Survey Sampling, Prentice Hall of India, New Delhi.
3. Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Asok, C. (1984). Sampling Theory of Surveys with Applications, Iowa State University Press and IARS.

Additional References

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1. Chaudhury, A. and Mukerjee, R. (1988). Randomized Response: Theory and Techniques, Marcel Decker, New York.
2. Murthy, M.N. (1977). Sampling Theory and Methods, Statistical Publishing Society, Kolkata.
3. Raj, D. and Chandhok, P. (1998). Sampling Theory. Narosa Publishing House , New Delhi.

STA C 202

Statistical Inference I

Full Marks: 100 **4 Credits**

Unit 1 Parametric models: Identifiable (indexing) parametric set up, estimation (point and interval) and testing of hypotheses, joint distribution of a sample and induced sampling distribution of a statistic; examples form standard discrete and continuous models. Likelihood function, information in data about the parameter, concept of non - information, sufficiency, Neyman factorizability criterion, likelihood equivalence, minimal sufficient statistic, exponential family, invariance property of sufficiency, Fisher information for one and several parameters model.

(12 Lectures)

Unit 2 Methods of estimation: maximum likelihood method, method of moments, method of minimum chi-square, method of scoring; choice of estimators based on unbiasedness, minimum variance, mean squared error, minimum variance unbiased estimators; Rao-Blackwell theorem, completeness, Lehmann-Scheffe theorem, necessary and sufficient conditions for MVUE, Cramer - Rao-Scheffe inequality. Consistency and CAN (statements only).

(12 Lectures)

Unit 3 Tests of Hypotheses: concepts of critical regions, test functions, two kinds of errors, size function, power function, level, MP test, Neyman-Pearson Lemma, likelihood ratio test, asymptotic distribution of L.R. statistic.

(12 Lectures)

Unit 4 Interval estimation; confidence level, construction of confidence intervals using pivots, shortest expected length confidence interval, construction of confidence interval using tests of hypothesis.

(12 Lectures)

Text Books

1. Casella. G and Berger R.L. (1990) Statistical Inference, Wordsworth and Brooks, California.
2.Hogg, R.V. and Craig, A.T. (2002). Introduction to Mathematical statistics, Pearson Education, Delhi.
3. Kale, B.K. (1999). A First Course on Parametric Inferences, Narosa Publishing House, New Delhi.
4. Rohatgi V. (1998). An Introduction to Probability and Mathematical Statistics. Wiley Eastern.

Additional References

1. Mukhopadhyay, Nitis. (2000). Probability and statistical inference, CRC Press.
2. Dudewicz, E.J. and Mishra, S.N. (1988). Modern Mathematical Statistics, John Wiley, New York.
3. Lehman, E.L. (1986). Testing of Hypothesis, John Wiley, Singapore.
4. Lehman, E.L. (1996). Theory of Point Estimation, John Wiley, Singapore
5. Rao, C.R. (1995), Linear Statistical Inference, Wiley Eastern, New Delhi.

STA O 203

Linear Models and Regression Analysis

Full Marks: 100 **4 Credits**

Unit 1 Gauss-Markov setup, estimability of parameters, normal equations and least-squares (LS) estimators, error and estimation spaces, variances and covariances of LS estimators, estimation of error variance, correlated observations, LS estimations with restrictions on parameters, simultaneous estimates of linear parametric functions. tests of hypotheses, linear models with restricted hypothesis, confidence intervals. (12 Lectures)

Unit 2 Introduction to one-way random effects linear models and estimation of variance components, mixed effects models. Linear regression: Simple and Multiple - estimation of parameters, hypothesis testing and interval estimation, prediction of new observations; prediction of new observations. Polynomial regression and orthogonal polynomials. (12 Lectures)

Unit 3 Model adequacy checking, residual analysis, residual plots, normal probability plots, detection of outliers, variance stabilising transformations, influential observations. Problems of multicollinearity. Power transformations for dependent and independent variables. (12 Lectures)

Unit 4 Nonlinear regression models: nonlinear LS, maximum likelihood estimation, transformations to linearize the model. Generalized linear model, analysis of binary and grouped data, logistic regression models: estimation and interpretation of parameters. Subset selection of explanatory variables, Mallow's Cp statistic. (12 Lectures)

Text Books

1. Draper, N. R. and Smith, H. (2011). Applied Regression Analysis, John Wiley, New York.
2. Montgomery, D. C.; Peck, E. A. and Vining G. G. (2006). Introduction to Linear Regression Analysis. John Wiley, New York.
3. Seber, G. A. F and Lee Alan J. (2014). Linear Regression Analysis, John Wiley, New York.
4. Cook, R. D. and Weisberg, S. (1982). Residual and influence in Regression. Chapman and Hall.
5. Draper, N. R. and Smith, H. (1998). Applied Regression Analysis, John Wiley, New York.
6. Searle, S. R. (1971). Linear Models. Wiley, New York.
7. Seber, G. A. F. and Wild, C. J. (2003). Non-linear Regression, Wiley.

Additional References

1. Chatterjee, S, and Hadi, Ali S. (2013). Regression Analysis by Example, John Wiley. New York.

STA O 204

Poverty, Human Development & Environmental Statistics

Full Marks: 50 **2 Credits**

UNIT I Concept of Human Development, Physical Quality of Life Index, Human Development Index and its Criticism, Gender-related Development Index. Socio-Economic Trend in India, National Income and its Concept, Estimation of National and State Incomes, Measurement of Unemployment.

(8 Lectures)

UNIT II Concept and Trend of Poverty, Determinants of Poverty and Inequality, Policies for Reduction of Poverty in India, Measurement of Poverty, Poverty Measurement by Kakwani and Sen. Concept of Income Inequality, Income Inequality Measurements.

(8 Lectures)

UNIT III Environmental Sustainability; Relation between poverty and environment and statistical tools.

(8 Lectures)

Reference Books

1. Betti, G. and Lemmi, A. (2008), "Advances on Income Inequality and Concentration Measures", Routledge.
2. Bodkin, D. D. (1995), "Environmental Science – Earth as a Living Planet", John Wiley & Sons, NY.
3. Gore, A. P. and Paranjpe, S. A. (2000) "A Course on Mathematical and Statistical Ecology", Kluwer.
4. Granzow, S. (2000), "Our Dream: A World Free of Poverty", World Bank/OUP, NY.
5. Lalwani, B. T. (2007), "Social Justice and Empowerment", Om Publication, ND.
6. Ludwig, J. A. and Juding, J. F. (1988), "Statistical Ecology", John Wiley & Sons, NY.
7. Meier, G. M. and Rauch, J. E. (2000), "Leading Issues in Economic Development", Oxford University Press, NY.
8. Nararyan, D. L. and Nagarjuna (2005), "Economics of Human Resource Development A Perspective Analysis", Serials Publications, ND.
9. Raju, M. L. (2007), "Women Empowerment: Challenges and Strategies", Deep and Deep Publications, ND.
10. Sen, A. (1997), "Poverty and Inequality", Oxford University Press, Oxford.
11. Atkinson, A. K. (2015), "Inequality", Harvard University press.
12. Breman, J. (2016), "On Pauperism - Past and Present", Oxford University Press.
13. Breman, J. (2015), "Pauperism in India", University of Copenhagen.

Additional Books

1. Bohringer, C. and Andreas, L. (2005), "Applied Research in Environmental Economics", Springer.
2. Marten, G. G. (2001), "Human Ecology: Basic Concepts for Sustainable Development", Earthscan Private Limited, London.
3. UNDP (Various Years), "Human Development Reports", http://hdr.undp.org.
4. Chatterjee, S. K. (2009), "Human Development and Its Quantification – a Holistic Approach", Ramakrishna Mission Vivekananda University, Belur Math, India.
5. Datta-Ray, B. (2000), "Population, Poverty and Environment in North East India", Associated Publishing House, ND.

STA C 205 (P)

Sampling, Inference I and Regression

Full Marks: 100 **4 Credits**

Problems based on following topics:

Section A:

- Simple random sampling – all possible samples
- Estimation using SRSWR and SRSWOR
- Estimation using SRSWR based on distinct units
- PPSWR & PPSWOR sampling – selection and estimation
- Stratified Sampling – estimation, sample allocation and construction of strata
- Estimation in linear and circular systematic sampling
- Estimation in cluster Sampling - equal and unequal cluster size
- Estimation in two-stage sampling - equal and unequal size units
- Estimation in double Sampling – ratio and regression estimator
- Estimation in double Sampling – for stratification

Section B:

- Plotting of likelihood function and finding m.l.e. of parameters – using numerical methods
- Estimation by the method of scoring for Cauchy and Chi – square distribution.
- Estimation by the method of minimum Chi – square
- Estimation by the method of moments
- Testing of hypotheses, power curves and confidence interval.
- Fitting of simple regression with one independent variable – inference about parameters
- Residual Plots and Tests for normality
- Fitting of polynomial regression and orthogonal polynomials
- Transformation on Y and/or X
- Fitting of Multiple regression
- Tests of hypothesis of one or more linear parametric functions, parallelism, intercepts
- Fitting of logistic regression

Section C:

- Simple linear regression
- Multiple linear regression
- Model adequacy checking
- Residual plots
- Normal probability plots
- Detection of outliers
- Variance stabilizing transformations
- Polynomial Regression
- Logistic regression
- Non-linear Regression

Text Books

1. Bhattacharyya, G.K. and Johnson, R.A. (1977). Statistical Concepts and Methods, John Wiley, New York.
2. Goon, A.M., Gupta, M.K. and Disrupt, B. (2000). Fundamentals of Statistics, World Press, Kolkata.
3. Hogg, R.V. and Tanis, E.A. (2003). Probability and Statistical Inference, Pearson Education, Delhi.
4. Chatterjee, S. and Price, B. (1991). Regression Analysis by Example, John Wiley, New York.
5. Draper, N.R. and Smith, H (1998). Applied Regression Analysis, John Wiley, New York.
6. Montgomery, D. C.; Peck, E. A. and Vining G. G. (2004). Introduction to Linear Regression Analysis . John Wiley, New York.
7. Seber, G. A. F and Lee Alan J. (2003). Introduction to Linear Regression Analysis, John Wiley, New York.
8. Krishnaiah, P.R. and Rao, C.R. (1988). Hand Book of Statistics, Vol. 6, Elsevier, Netherlands
9. Singh, D. and Choudhary, F.S. (1986). Theory and Analysis of Sample Survey Designs, New Age International Publishers, New Delhi.
10. Som, R.K. (1996). Practical Sampling Techniques, Marcel Dekker, New York

III SEMESTER

STA C 301

Design and Analysis of Experiments

Full Marks: 100 **4 Credits**

Unit 1 Concept of various experimental designs, basic principles of experimental designs, CRD, RBD and LSD and their analyses and uses, multiple range tests. (12 Lectures)

Unit 2 General factorial experiments - main and interaction effects, factorial experiments in CRD and RBD; principles of confounding and partial confounding for symmetric factorials, introduction to fractional factorial, split plot and split block designs. (12 Lectures)

Unit 3 Block designs, general properties, BIB designs with constructions and analysis; Introduction to PBIB designs; group divisible designs. (12 Lectures)

Unit 4 Response surface experiments, first order designs and orthogonal designs, Transformations, clinical trials, Cross-over designs, test treatment-control designs. (12 Lectures)

Text Books

1. Montgomery, C.D. (2013). Design and Analysis of Experiments, John Wiley, New York.
2. Cochran, W.G. and Cox, G.M. (1959). Experimental Designs, Asia Publishing House, Singapore.
3. Das, M.N. and Giri, N. (1979). Design and Analysis of Experiments, Wiley Eastern, New Delhi.
4. Giri, N. (1986). Analysis of Variance, South Asian Publishers.
5. Joshi, D.D. (1987). Linear Estimation and Design of Experiments, Wiley Eastern, New Delhi.

Additional References

1. Dean, Angela and Voss, Daniel (1999). Design and Analysis of Experiments, Springer-Verlag, New York.
2. Dey , Aloke (1986). Theory of Block Designs, Wiley Eastern, New Delhi.
3. Pearce, S.C. (1984). Design of Experiments, John Wiley, New York.
4. Searle, S.R. Casella, G. and McGulloch, C.E. (1992). Variance Components, John Wiley, New York.
5. Dey , Aloke (2010). Incomplete Block Designs, World Scientific, Singapore.
6. Raghavarao, D. and Laxmi, P. (2005) “Block Designs”, World Scientific, Singapore.

STA C 302

Statistical Inference II

Full Marks: 100 **4 Credits**

Unit 1 Monotone likelihood ratio property, UMP and UMPU tests, Karlin-Rubin theorem, Wald's SPRT with pre-specified errors of two kinds, OC and ASN functions and application.

(12 Lectures)

Unit 2 One sample location problem, sign test and signed rank test, one and two sample Kolmogorov Smirnov tests, Two sample location problems. Wilcoxon-Mann-Whitney test, normal score test, ARE of various tests based on linear rank statistics. Kruskal-Wallis K sample test, one and two sample U statistics, asymptotic distribution of U statistics.

(12 Lectures)

Unit 3 Basic concepts of decision theory; inference problems viewed as decision problem, Problem of classification, minimax approach and Bayes' approach, structure of Bayes' rule, complete class of rules, construction of minimax rule.

(12 Lectures)

Unit 4 Concepts and evaluation of subjective probability of an event; subjective prior distribution of a parameter. Bayes' theorem and computation of posterior distribution; natural conjugate family of prior for a model, loss function, Bayes' risk, Bayesian estimation of parameters of binomial, Poisson, normal and exponential distributions.

(12 Lectures)

Text Books

1. Bansal, A. K. (2007): Bayesian Parametric Inference, Narosa Publishing House, New Delhi.
2. Casella. G and Berger, R.L. (1990) Statistical Inference, Wordsworth and Brooks, California.
3. Ferguson, T.S. (1996). Mathematical Statistics- A Decision theory approach, Academic press, London.
4. Gibbons, J.D. (1985). Non-parametric Statistical Inference, Marcel Dekker, New York.
5. Kale, B.K. (1999). A first Course on Parametric Inference, Narosa Publishing House, New Delhi.
6. Rohatgi V. (1988). An Introduction to Probability and Mathematical Statistics, Wiley Eastern, New Delhi
7. Lehmann, E. L. (2015), "Theory of Point Estimation", 2ND Ed., Springer.

Additional References

1. Dudewicz, E.J. and Mishra, S.N. (1988). Modern Mathematical Statistics. John Wiley and Sons, New York.
2. Mukhopadhyay, N. (2000). Probability and Statistical Inference, CRC, London
3. Mukhopadhyay, N. (2006). Introductory Statistical Inference, CRC, London

STA O 303

Econometrics

Full Marks: 100 **4 Credits**

UNIT I Definition of Econometrics, Single equation linear model, types of Econometrics, Measurement scales of variables, population & sample regression functions, linearity, definition and specification of general linear model with assumptions, Stochastic specification of PRF; techniques of ordinary least squares (OLS) and Generalized least squares (GLS), difference between OLS and GLS. (12 Lectures)

UNIT II Problems of heteroscedasticity, autocorrelation and multicollinearity - their consequences and diagnosis - VIF, tolerance, eigenvalues, condition index, condition number and remedies; ridge regression with applications. (12 Lectures)

UNIT III Principal components regression and generalized inverse regression, concept of dummy variables and application in Regression, probit and logit regressions. (12 Lectures)

UNIT IV Distributed-lag models (DLM) specifications, estimation of parameters under various DLMs. Instrumental variables, method of restricted least squares. (12 Lectures)

Text Books

1. Anders, B. (2001), "Ridge Regression and Inverse Problems", Stockhome University, Sweden.
2. Apte, P. G. (1990), "Text Book of Econometrics", Tata McGraw Hill, ND.
3. Baltagi, B. H. (2005), "Econometrics", Springer (India), ND.
4. Gujarati, D. (2004), "Basic Econometrics", 4TH Ed., McGraw Hill, ND.
5. Gujarati, D. (2012), "Econometrics by Example", Indian Ed.
6. Gujarati, D., Dawn, C. P. and Gunasekar, S. (2011), "Basic Econometrics", 5TH Ed., McGraw Hill education.
7. Green, W. H. (2003), "Econometric Analysis", 5TH Ed., Prentice Hall, New Jersey.
8. Hansen, B. E. (2016), "Econometrics", Revised, University of Wisconsin, Madison.
9. Johnston, J. (1984), "Econometric Methods", McGraw Hill, NY.
10. Verbeek, M. (2004), "A Guide to Modern Econometrics", 2ND Ed., John Wiley & Sons, England.

Additional Books

1. Intrilligator, M. D. (1980), "Econometric Models – Techniques and applications", Prentice Hall of India, ND.
2. Judge, G. G., Griffiths, W. E., Hill, R. C., Lutkepohl, H. and Lee, T. C. (1985), "The Theory and Practice of Econometrics", John Wiley and Sons, NY.
3. Koutsoyiannis, A. (1977), "Theory of Econometrics", Macmillan, London.
4. Maddala, G. S. (1977), "Econometrics", McGraw Hill Book Company, Singapore.
5. Malinvaud, E. (1970), "Statistical Methods of Econometrics", North Holland, Amsterdam.
6. Schmidt, P. (1976), "Econometrics", Marcel Dekker, NY.
7. Theil, H. (1971), "Principles of Econometrics", John Wiley and Sons, NY.

STA O 304

Stochastic Processes

Full Marks: 50 **2 Credits**

Unit 1 Introduction to stochastic processes (sp's); classification of sp's according to state space and time domain, Countable state Markov chains (MC's), Chapman-Kolmogorov and spectral decomposition theorems, calculation of n-step transition probability and its limit, classification of states; transient and persistent MC, stationary distribution, random walk and gambler's ruin problem; applications in social, biological and physical sciences. (12 Lectures)

Unit 2 Discrete state space continuous time MC: Kolmogorov-Feller differential equations; Poisson process, birth and death process; applications to queues and storage problems, introduction to Wiener process, martingales and their uses. (12 Lectures)

Text Books

1. Adke, S. R. and Manjunath, S. M. (1984): An Introduction to Finite Markov Processes, Wiley Eastern.
2. Feller, W. (1968): Introduction to Probability and its Applications, Vol.1, Wiley Eastern, New Delhi
3. Medhi, J. (2013), "Stochastic Processes", 3RD Ed., Wiley Eastern.
2. Minh, D.L. (2000) Applied Probability Models, Duxbury Press.
3. Ross, S.M. (1996). Stochastic Processes, John Wiley and Sons.
4. Ross, S.M. (2007): Introduction to Probability Models (IXth edition). Elsevier, USA.

Additional References

1. Cinlar, E. (1975): Introduction to Stochastic Processes, Prentice Hall.
2.
3. Guttorp, P.(1995) Stochastic Modelling for Scientific Data, Springer.
4. Karlin, S. and Taylor, H. M. (1975): A First Course in Stochastic Processes, Vol.1, Academic Press.
5. Parzen, E. (1962): Stochastic Processes, Holden- Day. San - Francisco

STA C - 305 (P)

Design, Econometrics and Inference II

Full Marks: 100 **4 Credits**

Problems based on following topics:

Section A:

- Single factor design
- Multiple Range Test
- Randomized Complete Block Design (RCBD)
- Latin Square Design (LSD)
- Balanced Incomplete Block Design (BIBD)
- 2^n factorial experiments, n = 3, 4
- 3^n factorial experiments, n = 2, 3
- Complete confounding
- Partial confounding
- Split-plot design

Section B:

- Generalized Least Squares
- Detection of autocorrelation
- Detection of Heteroscedasticity
- Detection of Multicollinearity
- Principal Components Regression
- Ridge Regression
- Generalized Inverse Regression

Section C:

- One and two sample Sign and Signed rank tests
- One and two sample Kolmogorov-Smirnov tests & p - p plot
- Wilcoxon-Mann-Whitney test
- Normal Score Test
- Kruskal-Wallis K Sample Test
- Minimax estimation
- Hypothesis testing: UMP, UMPU tests, its power function and plotting
- Bayesian estimation under different priors and losses
- Bayesian estimation of risk under different priors and losses
- SPRT

Text Books

1. Anders, B. (2001), "Ridge Regression and Inverse Problems", Stockhome University, Sweden.
2. Baltagi, B. H. (2005), "Econometrics", Springer (India), ND.
3. Gujarati, D. (2004), "Basic Econometrics", 4th Ed., McGraw Hill, ND.
4. Green, W. H. (2002), "Econometric Analysis", Pearson Education Asia, ND.
5. Johnston, J. (1984), "Econometric Methods", McGraw Hill, NY.
6. Dudewicz, E.J. and Mishra, S.N. (1988). Modern Mathematical Statistics. John Wiley and Sons, New York.
7. Rohatgi V. (1988). An Introduction to Probability and Mathematical Statistics, Wiley Eastern, New Delhi

Reference Books

1. Gujarati, D. (2012), "Econometrics by Example", Indian Ed.
2. Gujarati, D., Dawn, C. P. and Gunasekar, S. (2011), "Basic Econometrics", 5TH Ed., McGraw Hill education.
3. Koutsoyiannis, A. (1977), "Theory of Econometrics", Macmillan, London.
5. Maddala, G. S. (1977), "Econometrics", McGraw Hill Book Company, Singapore.
6. Malinvaud, E. (1970), "Statistical Methods of Econometrics", North Holland, Amsterdam.

IV SEMESTER

STA C 401

Applied Multivariate Analysis

Full Marks: 100 **4 Credits**

Unit 1 Distribution of linear and quadratic forms in normal variables, expectations, variances and covariances, characteristic functions, independence of quadratic forms, conditions for a quadratic form to be distributed as chi-square and non-central chi-square, decomposition of quadratic forms, Cochran's theorem and James' theorem. (12 Lecturers)

Unit 2 MLEs of the parameters of multivariate normal distribution and their sampling distributions, Wishart distribution and its properties, tests of hypothesis about the mean vector of a multinormal population, Hotelling's T^2 - statistic, its distribution and applications. (12 Lecturers)

Unit 3 Classification and discrimination for two known populations: Bayes', minimax and likelihood ratio procedures, Mahalonobis D^2 - statistic and its application, sample discriminant function and discrimination based on Fisher's method, cluster Analysis and evaluation of clusters. (12 Lecturers)

Unit 4 Introduction to principal component analysis, canonical correlation analysis, factor analysis, MANOVA and its applications (sans derivation of the distribution of Wilk's λ). (12 Lecturers)

Text Books

1. Anderson, T.W. (1983). An Introduction to Multivariate Statistical Analysis, Wiley Eastern, New Delhi.
2. Johnson, R. and Wychern, D.W. (2002). Applied Multivariate Statistical Analysis, Pearson Education, Delhi.
3. Rao, C.R. (1995), Linear Statistical Inference, Wiley Eastern, New Delhi.
4. Sharma, S. (1996). Applied Multivariate Techniques. John Wiley, New York.
5. Singh, B.M. (2002). Multivariate Statistical Analysis, South Asian Publishers, New Delhi.

Additional References

1. Giri, N.C. (1977). Multivariate Statistical Inference. Academic Press, New York.
2. Kshirsagar, A.M. (1972). Multivariate Analysis, Marcel Dekker, New York.
3. Muirhead, R.J. (1982). Aspects of Multivariate Statistical Theory, John Wiley, New York.
4. Seber, G. A. F. (1984). Multivariate Observations, John Wiley, New York.

STA C 402

Time Series Analysis & Forecasting

Full Marks: 100 **4 Credits**

Unit 1 Time series data, graphical display and exploratory analysis; trend, seasonal and cyclical components; decomposition of series, moving average, exponential smoothing and Holt-Winters method

(12 lectures)

Unit 2 Stationary time Series, basic time series models: white noise, random walk, AR, MA and ARMA models, Box-Jenkins correlogram analysis, ACF and PACF, choice of AR and MA orders.

(12 lectures)

Unit 3 Non-stationary time series, ARIMA models, deterministic and stochastic trends, introduction to SARIMA and ARCH models.

(12 Lectures)

Unit 4 Model specification, estimation of ARIMA model parameters. Forecasting using exponential smoothing and Box – Jenkins model, Residual analysis and diagnostic checking.

(12 lectures)

Text Books

1. Brockwell, P. and Davis R.A.(2002). Introduction to Time Series and Forecasting, Springer.
2. Anderson, T.W. (1971). The Statistical Analysis of Time Series, John Wiley, New York.
3. Box, G.E.P., Jenkins, G.M. and Reinsel, G.C (2004). Time Series Analysis- Forecasting and Control, Pearson Education, Singapore.
4. Makridakis, S.G., Wheelwright, S.C. and Hyndman, R.J. (2005), Forecasting Methods and Applications, John Wiley and Sons.
5. Montgomery, D.C.,Jennings, C.L. and Kulachi, M.(2015). Introduction to Time Series Analysis and Forecasting, John Wiley and Sons.

Additional References

1. Enders, W.(2004). Applied Econometric Time Series, John Wiley and Sons.
2. Brokwel, P.J and Davis. R.A (1987). Time Series: Theory and Methods, Springer - Verlag, New York.
3. Fuller, W.A. (1976). Introduction to Statistical Time Series, John Wiley, New York.
4. Granger, C.W.J. and Newbold (1984). Forecasting Econometric Time Series, Academic Press, New York.
5. Shumway , R. H. and Stoffer, David S. (2006) Time Series Analysis and Its Applications: With R Examples. Springer-Verlag.

STA C 403 (Project)

Project Work

Full Marks: 50 **2 Credits**

Guidelines of the 'Project Work' are as follows:

1. A project work is intended to give students scope to apply and demonstrate statistical techniques.
2. The project report should clearly address a problem with methodology applied, hypotheses formulated and conclusions drawn.
3. The project work will be supervised by a faculty member allocated by the Department preferably during the third semester.
4. A student has to submit a project report/dissertation to the Department and give oral presentation of the project report before a board of examiners for evaluation.

STA C 404 (P)

Multivariate and Time Series Analyses and Optional Paper

Full Marks: 100 **4 Credits**

Problems based on following topics:

Section A:

- Generating random sample from multi normal population
- Estimation of mean and dispersion matrix
- Application of Hotelling's T^2 – statistic for single and two sample problems
- Discrimination between two multivariate normal populations with unknown parameters and common dispersion matrix
- Application of D^2 - Statistic
- Extraction of clusters
- Extraction of principal components and summarization of sample variations
- Canonical correlation analysis
- Factor analysis
- MANOVA (one way)

Section B:

- Correlogram Analysis and Interpretation
- Smoothing and Forecasting using simple exponential
- Forecasts using Holt and Winter model
- Modeling and Forecasting with pure MA/AR models
- Modeling and Forecasting with mixed ARMA models
- Fitting and Forecasting with ARMA models
- Modeling seasonal data using SARIMA and Forecasting
- Modeling volatility using ARCH
- Residual Analysis
- Diagnostic checking

Section C:

Any One from following Optional Papers

Operations Research

- Decision problems under uncertainty and risk.
- Solving linear Programming Problem using graphical method.
- Solving linear Programming Problem using simplex method.
- Use of big – M method.
- Use of two – phase method.
- Solving Transportation problems.
- Solving Assignment problems.
- Use of Wolfe's method for solving Quadratic programming problem.
- Deterministic Inventory problems.
- Queuing models M/M/1 and M/M/c.

Reliability Theory

- Hazard rate estimation for exponential and Gamma distribution (complete sample).
- Hazard rate estimation for Weibull distribution (complete sample).
- Hazard rate estimation for exponential and Gamma distribution (censored sample).
- Hazard rate estimation for Weibull distribution (censored sample).
- Estimation of Parameters of exponential and Gamma distribution (complete sample).
- Estimation of Parameters of Weibull distribution (censored sample).
- MLE and UMVE estimation of Reliability in different life distribution.
- MLE and UMME estimation of hazard rate for different life distribution.

- Reliability and Hazard rate estimation in Normal distribution
- Testing of hypothesis about the reliability function and its confidence interval for exponential and gamma

Population Dynamics and Demography

- Construction of age-sex Pyramid
- Construction of Whipple's, Myer's and UN indices
- Computation of mortality rates: CDR. ASDR, SDR
- Fitting of Gompertz and Makheham curves
- Construction of life tables: Complete and abridged
- Computation of fertility rates: CBR, GFR, TFR, Child Woman Ratio
- Computation of Reproduction rates: GRR and NRR
- Estimation of Intrinsic growth rate
- Population projections: Fitting of Modified Exponential and Logistic curves

Text Books

1. Brockwell, P. and Davis R.A.(2002). Introduction to Time Series and Forecasting, Springer.
2. Anderson, T.W. (1971). The Statistical Analysis of Time Series, John Wiley, New York.
3. Anderson, T.W. (1971). The Statistical Analysis of Time Series, John Wiley, New York.
4. Box, G.E.P. and Jenkins, G.M. (1976). Time Series Analysis- Forecasting and Control, Holden-day, San Francisco.
5. Granger, C.W.J. and Newbold (1984). Forecasting Econometric Time Series, Academic Press, New York.
6. Johnson, R. and Wychern, D.W. (2002). Applied Multivariate Statistical Analysis, Pearson Education, Delhi.
7. Seber, G.A.F. (1984). Multivariate Observations, John Wiley, New York.
8. International Institute of Population Sciences (1995). National Family Health Survey, 1992-93, Mumbai, IIPS.
9. International Institute of Population Sciences (2002). National Family Health Survey, 1998-99, Mumbai, IIPS
10. International Institute for Population Science (IIPS) and Macro International (2007). National Family Health Survey (NFHS – 3) 2005-06, Mumbai, IIPS.
11. Srinivasan, K. (1998). Basic Demographic Techniques and Applications. Sage Publications, New Delhi.
12. Bain L.J. (1991) Statistical Analysis of Reliability and Life Testing Models, Marcel Dekker, New York.
13. Nelson, W. (1982). Applied Life Data Analysis, John Wiley, New York.
14. Kanti, S., Gupta, P.K. and Singh, M.M. (1995). Operations Research, Sultan Chand & Sons, New Delhi.
15. Taha, H.A. (1982). Operational Research: An Introduction, Macmillan, New York.

Any One Course from STA C 405, STA C 406 and STA C 407

STA C 405

Reliability Theory

Full Marks: 100 **4 Credits**

Unit 1 Reliability concepts and measures; components and systems, coherent systems; reliability coherent systems, cuts and paths, modular decomposition, bounds and system reliability; structural and reliability importance components.

(12 Lectures)

Unit 2 Failure **time** distributions; reliability function, hazard rate, common failure time distributions; exponential, Weibull, gamma etc., estimation of parameters and tests in these models, notions of ageing; increasing failure rate (IFR).

(12 Lectures)

Unit 3 Increasing failure rate average (IFRA), not better than used (NBU), decreasing mean residual life (DMRL) and not better than used in expectation (NBUE), classes and their duals; loss of memory property of the exponential distribution; closures of these classes under formation of coherent systems, convolutions and mixtures.

(12 Lectures)

Unit 4 Univariate shock models and the distributions arising out of them; bivariate shock models, common bivariate exponential distributions and their properties, reliability estimation based on failure times in censored life tests and in tests with replacement of failed items; stress-strength reliability and its estimation.

(12 Lectures)

Text Books

1. Bain L.J. (1991) Statistical Analysis of Reliability and Life Testing Models, Marcel Dekker, New York.
2. Barlow R.E. and Proschan, F. (1985). Statistical Theory of Reliability and Life Testing, Holt Rinehart and Winston, New York.

Additional References

1. Lawless, J.F. (1982). Statistical Models and Methods of Life Time Data, John Wiley, New York.
2. Nelson, W. (1982). Applied Life Data Analysis, John Wiley, New York.

STAC 406

Operations Research

Full Marks: 100 **4 Credits**

Unit 1 Definition and scope of operations research; phases in operations research, models and their solutions, decision-making under uncertainty and risk, use of different criteria, Review of linear programming (LP) problems - duality theorem.

(12 Lectures)

Unit 2 Transportation and assignment problems; sensitivity analysis; non-linear programming; Kuhn Tucker conditions, Wolfe's and Beale's algorithms for solving quadratic programming problems.

(12 Lectures)

Unit 3 Analytical structure of inventory problems; Economic order quantity (EOQ) formula of Harris, its sensitivity analysis and extension allowing quantity discounts and shortages, multi-item inventory subject to constraints, P and Q- systems with constant and random lead items.

(12 Lectures)

Unit 4 Queueing models; specifications and effectiveness measures, steady-state solutions of M/M/1 and M/M/c models with associated distributions of queue length and waiting time, M/G/1 queue and Pollazcek-Khinchin result, steady state solutions of M/Ek/1, simulation.

(12 Lectures)

Text Books

1. Kanti, S., Gupta, P.K. and Singh, M.M. (1995). Operations Research, Sultan Chand & Sons, New Delhi.
2. Taha, H.A. (1982). Operational Research: An Introduction, Macmillan, New York.
3. Wagner, H.M. (1994). Principles of Operations Research, Prentice Hall of India, New Delhi.

Additional Reference

1. Hillier, F.S. and Leiberman, G.J. (1962). Introduction to Operations Research, Holden-day, San Francisco.

STAC 407

Population Dynamics and Demography

Full Marks: 100 **4 Credits**

Unit 1 Introduction to Population: Meaning of Population, Size, structure, distribution of population, the structure of demographic rates. Age-sex pyramids. Demographic data: Census, Registration system, Indian SRS, and surveys. NFHS- 2, 3 & 4. Evaluation of Quality of demographic data: Chandrasekaran-Deming formula, accuracy of data on sex and age: Whipple's, Myer's and UN indices.

(12 Lectures)

Unit 2 Mortality: concepts and rates, measures of infant mortality rate. Force of mortality, mortality laws - Gompertz and Makeham. Life table and its construction: complete and abridged, Greville's, Reed-Merrel's and Chiang's methods

(12 Lectures)

Unit 3 Fertility and Reproduction: Period and cohort measures. P/F ratio and own children method, reproductive measures. Nuptiality rates. Gross and net nuptiality tables, internal and international migration: concept and rates, uses of place of birth and duration of residence data.

(12 Lectures)

Unit 4 Theory of stable population model (one sex), quasi and stationary population. Lotka's stable population model. The equations characterizing a stable population, the effect of changes in fertility and mortality on age structure, growth rates, birth rates and death rates. Momentum of population growth. Population projection: Mathematical curves viz., growth curves, modified exponential, logistic curves and its properties, and their fitting, component method and matrix method of population projection.

(12 Lectures)

Text Books

1. Samuel H. Preston (2001). Demography: measuring and modeling population processes. Blackwell.
2. Shryock, H.S. (1976).The methods and Materials of Demography. Academic Press, New York.
3. Lundquist, J. H. and Anderton, D. L. (2014). Demography: The Study of Human Population, Waveland Press, Inc.
4. Preston, S. and Heuvline, P. (2000). Demography: Measuring and Modeling Population Process, Blackwell publishers Ltd.

Additional References

1. International Institute of Population Sciences (1995). National Family Health Survey, 1992-93, Mumbai, IIPS.
2. International Institute of Population Sciences (2002). National Family Health Survey, 1998-99, Mumbai, IIPS
3. International Institute for Population Science (IIPS) and Macro International (2007). National Family Health Survey (NFHS - 3) 2005-06, Mumbai, IIPS.
4. Keyfitz, N. and Caswell, H. (2005). Applied Mathematical Demography, Third Edition, Springer, New York.
5. Krishnan Namboodiri. (1996). A primer of Population Dynamics. Plenum.
6. Mishra, B.D (1995). An Introduction to The Study of Population. South Asian Publications, New Delhi.
7. Ram Kumar (1986).Technical Demography. Wiley Eastern, New Delhi.
8. International Institute for Population Science (IIPS) and Macro International (2007). National Family Health Survey (NFHS - 4) 2015-16, Mumbai, IIPS.