Central University of Rajasthan
Department of Statistics

2-year M. Sc. Statistics / Integrated M.Sc. Statistics VII-X Sem (2021 Batch onwards)

Proposed to be implemented for the students admitted in academic year 2026 for M.Sc. Programme.

and also for the students admitted in Integrated M.Sc. Statistics Programme in academic year 2021-22, 2022-23, 2023-24 from VII Semester Onwards

Department of Statistics

School of Mathematics Statistics and Computational Sciences

Central University of Rajasthan

Bandarsindri, NH-8, Kishangarh, Ajmer, Rajasthan

305801

Programme Objective:

The main objective of Two-year M.Sc. in Statistics programme in CURaj is to facilitate students to learn, practice and make career in the art of information analysis for the purpose of decision making on concerned problems. Analysis can be done by using well accepted principle and scientific methods developed in Statistics. Students should have an opportunity of better understanding the fundamentals of statistics and equip themselves to work as a professional statistician. Training in statistical computing will enhance their job opportunities and professional skills.

Learning outcome of this program: Post Graduates of the M.Sc. Statistics program will be able to:

PO1: Disciplinary Knowledge

Graduates will demonstrate a broad and integrated understanding of Statistics and its interrelated sub-disciplines, with in-depth knowledge in selected areas.

PO2: Statistical Reasoning & Problem Solving

Graduates will apply principles of probability and statistics to model random phenomena and solve real-world problems using appropriate analytical techniques.

PO3: Data Collection, Experimentation & Inference

Graduates will design sampling methods and experiments, analyze data, and draw valid statistical inferences to support evidence-based decision-making.

PO4: Scholarly Literacy & Lifelong Learning

Graduates will independently read, interpret, and critically evaluate statistical literature and online resources for continuous learning and professional growth.

PO5: Professional Competence & Career Readiness

Graduates will be prepared to work effectively in industry, research, government, healthcare, education, and analytics sectors, or pursue higher studies in statistics and related fields.

Structure of Two-year M.Sc. Statistics Programme

Semester I					
S.No.	**Old Course Code**	**Revised Code**	**Title of Courses**	**Type of Course**	**Credits**
1.	STA 411	6.0STA01	Probability Theory	CORE	4
2.	STA 412	6.0STA02	Distribution Theory	CORE	4
3.	STA 413	6.0STA03	Sampling Theory	CORE	4
4.	STA 414	6.0STA04	Linear Algebra and its Applications	CORE	3
5.			Course from department/ another department/ Open Elective	Non-DSE	3
6.	STA 461	6.0STA61	Professional Communication	AEC	2
					Total Credits = 20

Semester II					
S.No.	**Old Course Code**	**Revised Code**	**Title of Courses**	**Type of Course**	**Credits**
1.	STA 416	6.0STA06	Theory of Estimation and Testing of Hypothesis	CORE	4
2.	STA 417	6.0STA07	Regression Analysis	CORE	4
3.	STA 418	6.0STA08	Stochastic Processes	CORE	4
4.	STA 419	6.0STA09	Design and Analysis of Experiments	CORE	3
5.			DSE : From list of electives / MOOCS	DSE/ MOOCS	3
6.	STA 431	6.0STA81	Minor Project	SEC	2
					Total Credits = 20

Semester III					
S.No.	**Old Course Code**	Revised Code	**Title of Courses**	**Type of Course**	**Credits**
1.	STA 511	6.5STA01	Multivariate Time Series Analysis and Forecasting	CORE	4
2.	STA 512	6.5STA02	Multivariate Analysis	CORE	4
3.	STA 513	6.5STA03	Survival Analysis	CORE	4
4.	STA		DSE	DSE	3
5.	STA		DSE	DSE	3
6	STA 561	6.5STA61	Seminar / Summer Internship presentation	AEC	2
					Total Credits = 20

Semester IV					
S.No.		Revised Code	**Title of Courses**	**Type of Course**	**Credits**
1.	STA 531	6.5STA81	Major Research Project (in Industry or in Academia)	RP	20
					Total Credits = 20

Major: (code lie in 01-30)

GE/DSE: Generic Elective/ Discipline Specific Elective (code lies in 31-40)

IDC: Inter-Disciplinary Course (code lies in 41-49)

SEC: Skill Enhancement Course (code lies in 51-59)

AEC: Ability Enhancement Course (code lies in 61-69)

RP: Research Project (code lies in 81-85)

List of Electives

Semester VIII					
S.No.	**Old Course Code**	**Revised Code**	**Title of Courses**	**Type of Course**	**Credits**
1.	STA 481	6.0STA31	National Development Statistics	DSE	3
2.	STA 482	6.0STA32	Computer Intensive Statistical Methods	DSE	3
3.	STA 484	6.0STA33	Machine Learning	DSE	3
Semester IX					
S.No.	**Old Course Code**	**Revised Code**	**Title of Courses**	**Type of Course**	**Credits**
1.	STA 581	6.5STA31	Econometrics.	DSE	3
2.	STA 582	6.5STA32	Discrete Data Analysis	DSE	3
3.	STA 583	6.5STA33	Nonparametric Statistics	DSE	3
4.	STA 584	6.5STA34	Tools for Data Science	DSE	3
5.	STA 585	6.5STA35	Bayesian Inference	DSE	3
6	STA 586	6.5STA36	Optimization Techniques	DSE	3

Semester I

Course Name: Probability Theory		**Course Code: STA411/6.0STA01**
Teaching Scheme	**Examination Scheme**	Credit: **04**
Theory: 3 hrs/ week	**Continuous Internal Assessment(CIA):** 20+20 Marks	3/0/2
	End Semester Examination(ESE): 60 Marks	
Tutorial: 1 hrs/ week	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Basic Probability
2. Convergence of sequence and series

Course Objective:

1. The main purpose is to introduce Probability Theory under axiomatic approach and develop further theory and concepts including the limit behaviours.

Course Outcomes: After completion of this course student will able to

1. Recognize the concept of field, sigma field, probability space, probability measure.
2. Understand the concept of convergence of sequences of random variables.
3. Apply various inequalities to solve complex statistical problems.
4. List various types of random variables.
5. Apply different probability theorems and laws for solving different mathematical problems.

Unit 1 **20**

Classes of sets, field and sigma fields, limit of sequences of subsets, sigma field generated by a class of subsets, Borel field, Borel sigma field. Measure, probability measure, probability space, properties of probability measure-continuity, mixture of probability measures. Lebesgue and Lebesgue - Steltjes measures on R.

Unit 2 **15**

Distribution functions of discrete rvs, continuous and mixed type rv, decomposition of a df. Expectation of rv and its properties. Properties of Expectations. Characteristic function, simple properties.Inversion theorem and uniqueness property. Inequalities: Jensen's, Markov's, Chebychev's, Holder's and Lyapounov inequalities with its applications.

Unit 3 **15**

Independence of two events and n(>2) events, sequence of independent events. Monotone convergence theorem, Fatous Lemma, Dominated Convergence theorem, Borel - Cantelli Lemma, and their applications. Convergence of sequence of random variables, Convergence in distribution, continuity theorem (Statement only), Almost sure convergence, a characterizing property, convergence in probability, uniqueness of limit, Yule Slutsky results and preservation under continuous transform.(Statements only), convergence in r^{th} mean, interrelationships.

Unit 4 **10**

Weak and Strong laws of large numbers, Kolmogorov's three series theorem for almost sure convergence (Statement only), Demoivre-Laplace, Liaponove's, Lindeberg-Feller theorems on CLT (Statement only).

Reference/ Text Books:

1. Rao, B. P. (2009). A first course in probability and statistics. World Scientific.
2. Meyer, P.A. (1970) An Introduction to Probability and Its Applications. PHI
3. Rohatgi V.K & A.K. MD. Ehsanes Saleh (2001): An Introduction to Probability Theory and Mathematical Statistics, 2nd. John Wiley and Sons.
4. Allan Gut (2011) Probability : A Graduate Course. Springer

COs – POs Mapping matrix for STA411/6.0STA01: Probability Theory

(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	2	2
CO-2	3	3	2	1	2
CO-3	3	3	2	1	3
CO-4	3	2	1	1	2
CO-5	3	3	2	1	3
Total	**15**	**13**	**8**	**6**	**12**
Average	**3**	**2.6**	**1.6**	**1.2**	**2.4**

Course Name: Distribution Theory		**Course Code: STA412/6.0STA02**
Teaching Scheme	**Examination Scheme**	**Credit: 04**
Theory: 3 hrs/ week	**CIA:** 20+20 Marks	3/0/2
	ESE: 60 Marks	
Tutorial: 2 hrs/ week	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Statistical inference
2. Probability distributions.

Course Objective:

1. Concept development and visualization of Decision theory. Also, Knowledge of Non parametric statistic and related tests.

Course Outcomes: After completion of this course student will able to

1. Know about Statistical Decision Problem and different decision rules, priors and loss function.
2. Basic idea of Sequential procedures.
3. Application of nonparametric statistics and related test.

Unit 1 **15**

Weibull, Pareto, lognormal, Laplace, Cauchy, logistic, Rayleigh distribution their properties and applications. Non-central chi-square, t and F distributions. Generalized error distribution and its applications.

Unit 2 **15**

Compound, truncated and mixture distributions. Convolutions of two distributions. Beta Generated family of Distribution, Gamma generated Family of distribution.

Unit 3 **15**

Order statistics: their distributions and properties. Joint, marginal and conditional distribution of order statistics. The distribution of sample range and sample median. Extreme values and their asymptotic distribution (statement only) with applications.

Unit 4 **15**

Bivariate distributions, Multinomial distribution, Marshall-Olkin bivariate exponential distribution, bivariate normal distribution, marginal and conditional distribution, mgf, some properties. Plotting of bivariate normal density function.

Reference/Text Books:

1. Berger, J. O. (2013). Statistical decision theory and Bayesian analysis. Springer Science & Business Media.
2. Bernardo, J. M., & Smith, A. F. (2009). Bayesian theory (Vol. 405). John Wiley & Sons.
3. Robert, C. P. (2007). The Bayesian choice: from decision-theoretic foundations to computational implementation (Vol. 2). New York: Springer.
4. Ferguson, T. S. (2014). Mathematical statistics: A decision theoretic approach (Vol. 1). Academic press.
5. Casella, G., & Berger, R. L. (2021). Statistical inference. Cengage Learning.
6. Rohatgi, V. K., & Saleh, A. M. E. (2015). An introduction to probability and statistics. John Wiley & Sons.
7. Kotz, S., Balakrishnan N. and Johnson N. L. (2000): Continuous Multivariate Distributions, Volume 1, Models and Applications, John Wiley & Sons.

COs – POs Mapping matrix for STA412/6.0STA02: Distribution Theory
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	1	1	2
CO-2	3	3	2	1	2
CO-3	3	3	2	1	3
CO-4	3	3	2	1	3
CO-5	2	3	1	1	3
Total	**14**	**15**	**8**	**5**	**13**
Average	**2.8**	**3.0**	**1.6**	**1**	**2.6**

Course Name: Sampling Theory		**Course Code: STA413/6.0STA03**
Teaching Scheme	**Examination Scheme**	**Credit : 4**
Theory: 3 hrs/ week	**CIA:** 20+20 Marks	3/0/2
	ESE: 60 Marks	
Practical: 2 hrs/ week	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Descriptive Statistics
2. Probability and probability distributions
3. Statistical Inference
4. Knowledge of R

Course Objective: After successfully completing this course, students should ordinarily expect to be able to:

1. Describe different types of population approaches.
2. Describe different methods of sampling designs
3. Describe different methods of estimation under double sampling scheme
4. Describe non-sampling errors in a sample survey

Course Outcomes: After completion of this course student will able to

1. Understand the concepts of super population, various standard sampling designs and solve problems related to them.
2. Understand the concepts of unequal probability sampling, PPS sampling (PPSWOR/WR) and solve problems related to them.
3. Understand the concepts of double sampling, methods of estimation under double sampling and solve problems related to them.
4. Understand the concepts of cluster sampling, two-stage sampling and solve problems related to them.
5. Understand the non-sampling errors and handling the non-response in sample surveys and solve related problems.

Course Content:

Unit 1 **15**

Fixed population and super-population approaches. Distinct features of finite population sampling, Review of basic methods of simple random sampling and stratified random sampling. Post stratification, Deep stratification, Controlled sampling, estimators along with basic statistical properties, exercises.

Unit 2 **17**

Unequal probability sampling: PPSWR/WOR methods (including Lahiri's scheme) and Des-Raj estimator, Murthy estimator (for n=2). Horvitz Thompson Estimator of finite population total/mean, Expression for Variance (HTE) and its unbiased estimator, Issue of non-negative variance estimation, exercises.

Unit 3 **13**

Review of the use of supplementary information for estimation, concept of double sampling, two-phase sampling, stratification estimator, ratio, product and regression estimators with their properties under double sampling, Some unbiased ratio type estimators for population mean, exercises.

Unit 4 **15**

Review of cluster sampling (equal cluster size), cluster sampling (unequal cluster size), concept of two-stage sampling, non-sampling error with special reference to non-response problems and its treatments, exercises.

Reference/ Text Books:

1. Cochran, W.G. (2007): Sampling Techniques , Third Edition, Wiley India Pvt. Ltd., New Delhi.
2. Murthy, M. N. (1977): Sampling Theory and Methods, Statistical Publishing Society, Kolkata.
3. Cochran, W.G.(2007): Sampling Techniques , Third Edition, Wiley India Pvt. Ltd., New Delhi. 2. Murthy, M. N. (1977): Sampling Theory and Methods, Statistical Publishing Society, Kolkata.
4. Singh, D. and Chaudhary, F. S. (1986): Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd., New Delhi.
5. RaghunathArnab (2017): Survey Sampling Theory and Applications, Academic Press, Elsevier.
6. Mukhopadhyay P (2008): Theory and methods of survey sampling. Prentice-Hall of India, New Delhi.
7. Latpate, R., Kshirsagar, J., Gupta V. and Chandra, G. (2021). Advanced Sampling Methods, Springer.

E-Resources:

1. https://nptel.ac.in/courses
2. http://mospi.nic.in/

COs – POs Mapping matrix for STA413/6.0STA03: Sampling Theory
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	3	1	3
CO-2	3	3	3	1	3
CO-3	3	3	3	1	3
CO-4	3	3	3	1	3
CO-5	2	3	3	1	3
Total	**14**	**15**	**15**	**5**	**15**
Average	**2.8**	**3.0**	**3.0**	**1**	**3.0**

Course Name: Linear Algebra and its Applications		Course Code: STA414/6.0STA04
Teaching Scheme	**Examination Scheme**	Credits**: 3**
Theory: **2**	**CIA:** 20+20 Marks	2/0/1
Tutorial**: 1**	**ESE:** 60 Marks	
	Total=100 Marks	

Course Pre-requisites: No

Course Objectives: To develop the knowledge of matrices, Linear transformations, Eigenvalues and vectors.

Course Outcomes: After completing the course, the student shall be able to:

1. Solve systems of linear equations using multiple methods, including Gaussian elimination and matrix inversion.
2. How to apply all of the essential vector and matrix operations for machine learning and data science
3. Carry out matrix operations, including inverses and determinants.
4. Implement linear algebra concepts in scientific programming languages, and apply linear algebra concepts to real datasets
5. Interpret solutions of linear algebraic models and assess numerical stability in real-world data problems.

Course Content:

Unit-1	Matrices, System of Linear Equations, Elementary Row Operations, Row Reduced Matrices, Invertible Matrices. Fields, Vector spaces, Subspaces, Linear Combinations, Linear span, Linear dependence and Linear independence of vectors, Basis and Dimension, Ordered Basis, Finite dimensional vector spaces.	**10**
Unit-2	Linear transformations and their representation as matrices, Kernel and Image of a linear transformation, Rank and Nullity Theorem, Change of Basis, Eigenvalues and Eigenvectors of a linear transformation (matrices), Eigen decomposition of symmetric matrices, Eigen decomposition of singular matrices, Characteristic polynomial and minimal polynomial, Diagonalization of linear operators, invariant subspaces, Jordan	**12**
Unit-3	Normed space, Inner product spaces, Cauchy-Schwarz-inequality, Orthogonal vectors, Orthonormal sets and bases, Projections, decompose vector to orthogonal components, Gram-Schmidt algorithm. Positive Definite and Positive Semi-definite Matrices, Rayleigh quotient, Linear functional on an Inner Product Space and Adjoint of a Linear operator, Self-adjoint operators, Normal Operators, Spectral theory of matrix, Spectral Decomposition, The Trace Operator. Quadratic forms.	**11**
Unit-4	Numerical methods: Bisection Method, Newton Raphson, Steepest Ascent, method of conjugate gradients; Direct and iterative methods for solving a linear system of equations: Gaussian elimination, LU factorization, Cholesky method, QR factorization, Householder's matrices, Jacobi's method, Gauss-Seidel method, successive over-relaxation methods (SOR), conditioning of a problem.	**12**

Text Book:

1. Sheldon Axler, “Linear Algebra Done Right (Undergraduate Texts in Mathematics)”,Springer, third edition, 2015.
2. Lloyd N. Trefethen and David Bau, III, “Numerical Linear Algebra”, SIAM,1997.

Reference Books:

1. Gilbert Strang, “Linear Algebra and learning from data”, Wellesley-Cambridge Press, 2019.
2. Mike Cohen, “Practical Linear Algebra for Data Science”, O'Reilly,1st Edition, 2022

E-Resources:

1. https://archive.nptel.ac.in/courses/111/106/111106051/

COs – POs Mapping matrix for STA414/6.0STA04: Linear Algebra and its Applications (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	1	1	3
CO-2	3	3	2	1	3
CO-3	3	3	1	1	2
CO-4	2	3	2	1	3
CO-5	2	3	2	1	3
Total	**13**	**15**	**8**	**5**	**14**
Average	**2.6**	**3**	**1.6**	**1**	**2.8**

Course Name: Professional Communication		Course Code: STA461/6.0STA61
Teaching Scheme	**Examination Scheme**	**Credit: 2**
Theory: 2	**CIA:** 20+20 Marks	
Tutorial: 0	**ESE:** 60 Marks	
	Total=100 Marks	

Course Prerequisites: No

Course Objectives: To develop the knowledge of communication theory and processes.

Course Outcomes: After completing the course, the student shall be able to:

1. Understand and apply communication theory.
2. Critically think about communication processes and messages.
3. Write effectively for a variety of contexts and audiences.
4. Communicate with confidence in professional environment
5. Collaborate effectively in teams and deliver clear oral presentations using appropriate communication strategies.

Course Content:

Unit-1 **Fundamentals of Communication** **7**

- Definition, Process, Importance of Communication
- Types of Communication
- Purpose of Professional Communication
- Barriers to Communication

Unit-2 **Oral Communication:** **7**

Listening Skill –

- Effective Listening
- Intensive Listening vs Extensive listening
- Techniques of Effective Listening
- Listening and Note Taking

Speaking Skills

- **Paralinguistic features**
  - Rate
  - Pauses
  - Volume
  - Pitch/Intonation/Voice Modulation
  - Pronunciation and Articulation
- **Activities**
  - Group Discussions
  - Debates
  - Interviews
  - Public Speaking

Readings Skills

- Effective Reading
- Types of Reading (Skimming, Scanning, Extensive Reading, Intensive Reading)

Unit-3 **Written communication:** **8**

- Academic Writing
- Critical Thinking
- Technical Writing vs Creative Writing
    - Paragraph Writing (structure, construction, coherence and cohesion)
    - Business Letters (Acknowledgement letter, Appreciation letter, Order letter)
    - Business Reports
    - Research Papers
    - Advertising, Notices, Emails
    - Resume writing, Cover Letter

Soft Skills:

Unit-4 **8**

- Body Language – Personal Appearance, Gesture, posture, facial expression, eye contact
- Proxemics/ Space Distance
- Presentation Skills

Text Books:

1. Banerjee Meera & Mohan Krishna, "Developing Communication Skills", Macmillan Publications, 1990.
2. Chaturvedi, P.D., "Business Communication", Pearson Publications,2013

Reference Books:

1. M.J. Mathew," Business Communication", RBSA Publications, 2005.
2. Taylor Shirley, "Communication for Business", Pearson Publications,2005

E-Resources:

1. https://nptel.ac.in/courses/102104061
2. https://nptel.ac.in/courses/102104061

COs – POs Mapping matrix for STA461/6.0STA61: Professional Communication (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	2	1	1	2	2
CO-2	2	2	1	2	2
CO-3	1	1	1	2	3
CO-4	1	1	1	2	3
CO-5	1	1	1	2	3
Total	**7**	**6**	**5**	**10**	**13**
Average	**1.4**	**1.2**	**1**	**2**	**2.6**

Semester II

Course Name: Theory of Estimation and Testing of Hypothesis		**Course Code: STA416/6.0STA06**
Teaching Scheme	**Examination Scheme**	**Credit: 04**
Theory: 3 hrs/ week	CIA I & II = 20+20 marks	
Tutorial: 1 hrs/week	ESE: 60 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Standard probability distribution

Course Objective:

2. The main purpose is to make an individual understand basic theoretical knowledge about fundamental principles of statistical inference.

Course Outcomes: After completion of this course student will able to

1. Recognize different methods of parameter estimation
2. Recall various properties of estimators
3. Apply different statistical test procedures for different testing of hypothesis problems
4. Compare different statistical test through power comparison.
5. Analyze various real life data sets using tests of hypothesis.

Course Content:

Unit No.	Unit Contents	No. of Hrs
Unit 1	Criteria of a good estimator: unbiasedness, consistency, efficiency and sufficiency. Concept of mean squared error. Fisher-Neyman factorization theorem, Family of distributions admitting sufficient Statistic. Point estimation, Maximum likelihood method (MLE), moments, Least squares method. Method of minimum chi-square and percentiles. Properties of maximum likelihood estimator (with proof). Successive approximation to MLE, Method of scoring and Newton-Raphson method.	15
Unit 2	Cramer-Rao inequality and its attainment, Completeness and minimal sufficient statistic, Ancillary statistic, Basu theorem, Uniformly minimum variance unbiased estimator (UMVUE). Rao-Blackwell and Lehmann-Scheffe theorems and their applications, Asymptotic efficiency and asymptotic estimator, consistent asymptotic normal (CAN) estimator. Cramer-Huzurbazar theorem (statement only), Delta method and its application	15
Unit 3	Statistical Hypothesis, critical region, types of errors, level of significance, power of a test, Test function, Randomized and non-randomized tests, Most powerful test and Neyman-Pearson lemma. MLR family of distributions, unbiased test. Uniformly most powerful test. Uniformly most powerful unbiased test. Likelihood ratio test with its properties.	15
Unit 4	Confidence interval, confidence level, construction of confidence intervals using pivots, Determination of confidence intervals based on large and small samples, Coverage probability, uniformly most accurate one sided confidence interval and its relation to UMP test for one sided null against one sided alternative hypotheses.	15

Reference/ Text Books:

1. Casella, G., & Berger, R. L. (2021). Statistical inference. Cengage Learning.
2. Mukhopadhyay, P. (2012). Theory of Probability. New Central Book Agency.
3. Rao, C. R., Rao, C. R., Statistiker, M., Rao, C. R., & Rao, C. R. (1973). Linear statistical inference and its applications (Vol. 2, pp. 263-270). New York: Wiley.
4. Rohatgi, V.K. (1976): An Introduction to Probability Theory and Mathematical Statistics, Wiley

Eastern
5. Kale, B. K. (2005). A first course on parametric inference. Alpha Science Int'l Ltd..
6. Lehmann, E. L., & Lehmann, E. L. (1986). Testing statistical hypotheses (Vol. 2). New York: Wiley.

COs – POs Mapping matrix for STA416/6.0STA06: Theory of Estimation and Testing of Hypothesis
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	2	1	2
CO-2	3	2	1	1	2
CO-3	3	3	3	1	3
CO-4	3	3	2	1	3
CO-5	2	3	3	1	3
Total	**14**	**13**	**11**	**5**	**13**
Average	**2.8**	**2.6**	**2.2**	**1**	**2.6**

Course Name: Regression Analysis		**Course Code: STA417/6.0STA07**
Teaching Scheme	**Examination Scheme**	**Credit: 04**
Theory: 3 hrs/ week	CIA I & II = 20+20 marks ESE: 60 Marks	
Practical: 2 hrs/ week	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Correlation
2. Simple linear regression
3. Linear algebra
4. Exponential family of distributions

Course Objective:

1. The main purpose is to provide the theoretical foundations for the Linear Estimation Theory and Regression Analysis.

Course Outcomes: After completion of this course student will able to

1. Develop the linear predictive models and their extensions in nonlinear models, generalized models.
2. Diagnose and apply corrections to some problems with the generalized linear model found in real data.
3. Address practical problems and give a sound scientific interpretation to the results.
4. Assess the model using standard criterions.
5. Use standard statistical software to develop models and analyze data that arise from different fields.

Course Content:

Unit No.	**Unit Contents**	**No. of Hrs**
1.	Theory of linear estimation, estimable function, multiple regression model, least squares estimator and its properties, variance and covariance of least squares estimator, BLUE, estimation space, error space, Gauss-Markov theorem in linear estimation. Confidence interval estimation, prediction interval, distribution of quadratic forms for normal variables: related theorems (statements only), hypothesis testing for model for general linear hypothesis, testing of individual regression coefficients. Residual analysis: different types of residuals, residual plots.	15
2.	Dummy variables and their use in regression analysis. Multicollinearity: Consequences, detection and remedies, ridge regression. Variable Selection Procedures: R-square, adjusted R-square, Mallows' Cp, forward, backward and stepwise selection methods, AIC, BIC. Variance stabilizing transformations. Stepwise regression.	15
3.	Fundamental concept of generalized linear model (GLM), exponential family of random variables. Link functions such as Logit, Probit, binomial, inverse Gaussian, gamma. Nonlinear models, ML estimation in nonlinear models. Large sample tests about parameters, goodness of fit, analysis of deviance. Variable selection: AIC and BIC.	15
4.	Logistic regression: logit, probit and cloglog model for dichotomous data with single and multiple explanatory variables, ML estimation, large sample tests about parameters. Hosmer-Lemeshow test, ROC curve.	15

Reference/ Text Books:

1. Montgomery, D. C., Peck, E. A., & Vining, G. G. (2021). Introduction to linear regression analysis. John Wiley & Sons.
2. Kutner, M. H., Nachtsheim, C. J., Neter, J., & Wasserman, W. (2004). Applied linear regression models (Vol. 4, pp. 563-568). New York: McGraw-Hill/Irwin.

3. Hosmer Jr, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). Applied logistic regression (Vol. 398). John Wiley & Sons.

4. McCullagh, P., & Nelder, J. A. (2019). Generalized linear models. Routledge.

E-Resources:

1. https://nptel.ac.in/courses/111105042

COs – POs Mapping matrix for STA 417/6.0STA07: Regression Analysis (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	2	1	3
CO-2	3	3	3	1	3
CO-3	2	3	2	1	3
CO-4	3	3	2	1	3
CO-5	2	3	2	1	3
Total	**13**	**15**	**11**	**5**	**15**
Average	**2.6**	**3.0**	**2.2**	**1**	**3.0**

Course Name: Stochastic Processes		**Course Code: STA418/6.0STA08**
Teaching Scheme Theory: 3 hrs/ week Tutorial: 1 hrs/ week	**Examination Scheme** CIA I & II = 20+20 marks ESE: 60 Marks Total: 100 Marks	**Credit 04**

Course Pre-requisites: Student must have knowledge of

1. Random variables
2. Conditional probability
3. Generating functions

Course Objective:

1. The main objective of the paper is to provide theoretical foundations of Stochastic Processes and to introduce different Stochastic/Random Processes and their applications.

Course Outcomes:

1. Differentiate between various types of stochastic processes.
2. Understand Markovian property
3. Evaluate higher transition probabilities.
4. Apply stochastics models in business problems.
5. Recognize applications of branching, Brownian and renewal processes

Course Content:

Unit No.	Unit Contents	No. of Hrs
1.	Definition of stochastic process, classification of stochastic processes according to state space and time domain, finite dimensional distributions. Examples of various stochastic processes. Definition of Markov chain. Examples of Markov chains, Formulation of Markov chain models, initial distribution, transition probability matrix, Chapman-Kolmogorov equations, calculation of *n*-step transition probabilities. Simulation of Markov Chain.	15
2.	Classification of states, irreducible Markov chain, period of the state, random walk and Gambler's ruin problem, first entrance theorem, first passage time distribution. Long-Run proportions and limiting probabilities, relation with mean recurrence time, stationary distribution.	15
3.	Continuous time Markov Chain: Poisson process and related inter-arrival time distribution, compound Poisson process, Pure birth process, pure death process, birth and death process, problems, Renewal processes, Elementary renewal theorem (statement only) and its applications	15
4.	Galton-Watson Branching process. Generating functions and its properties, moments. Probability of ultimate extinction. Distribution of population size and association results. Simulation of branching process. Martingales, stopping times. Introduction to Brownian motion process and its basic properties.	15

Reference/ Text Books:

1. Kulkarni, V. G. (2016). Modeling and analysis of stochastic systems. Chapman and Hall/CRC.
2. Medhi J. (2009). Stochastic Process. New Age International Publications.
3. Cinlar E. (2013). Introduction to Stochastic Process. Courier Corporation.
4. Ross S. (1996): Stochastic Processes. Wiley.
5. Hoel, P. G., Port, S. C., & Stone, C. J. (1986). Introduction to stochastic processes. Waveland Press.
6. Pinsky, M., & Karlin, S. (2010). An introduction to stochastic modeling. Academic press.

COs – POs Mapping matrix for STA418/6.0STA08: Stochastic Processes
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	2
CO-2	3	3	1	1	2
CO-3	3	3	2	1	2
CO-4	2	3	2	1	3
CO-5	3	3	2	1	3
Total	**s**	**14**	**8**	**5**	**12**
Average	**2.8**	**2.8**	**1.6**	**1**	**2.4**

Course Name: Design and Analysis of Experiments		**Course Code: STA419/6.0STA09**
Teaching Scheme	**Examination Scheme**	**Credit 03**
Theory: 2 hrs/ week	CIA I & II = 20+20 marks ESE: 60 Marks	
Practical: 2 hrs/ week	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Linear algebra
2. Basic design of experiments

Course Objective:

1. Enable to plan, design and conduct experiments efficiently and effectively, and analyze the resulting data to obtain objective conclusions.

Course Outcomes: After completion of this course student will able to

1. Understand the potential practical problems and applications of design of experiments in various fields.
2. Build a deeper understanding, and tools for analysis of experiments.
3. Describe how the analysis of the data from the experiment should be carried out.
4. Use a statistical computing packages to analyze real-life data.
5. Appreciate the advantages and disadvantages of a design for a particular experiment.

Course Content:

Unit No.	**Unit Contents**	**No. of Hrs**
1.	Basic principle of experimental design, overview of RBD, CRD and LSD. Purpose of analysis of covariance. Practical situations where analysis of covariance is applicable. Model for analysis of covariance in CRD and RBD. Estimation of parameters (derivations are not expected). Preparation of analysis of covariance (ANOCOVA) table, test for $\beta = 0$, test for equality of treatment effects (computational technique only).	15
2.	Contrasts, orthogonal contrasts, Scheffé's method for comparing contrasts; Comparing pairs of treatment means: Tukey's test, Fisher least significant difference method, comparing treatment means with a control. General theory of intra block analysis of block design, connectedness and balancing block design, incomplete block design, intra block analysis of BIBD and its properties.	15
3.	Concepts of factorial designs, main effects, and interaction effects, The two-factor factorial design and its analysis using fixed effect model, The general factorial design, Analysis of replicated and unreplicated 2^k full factorial designs. Blocking and confounding in a 2^k factorial design. Construction and analysis of 2^{k-p} fractional factorial designs and their alias structures.	15
4.	The 3^k full factorial design and its analysis using fixed effect model. Response surface methodology: the method of steepest ascent, analysis of the response surface using first and second order models, characterizing the response surface, ridge systems, multiple responses, designs for fitting response surfaces: simplex design, central composite design (CCD), The concepts of nested and split-plot designs.	15

Reference/ Text Books:

1. Montgomery, D. C. (2017). Design and analysis of experiments. John Wiley & sons.
2. Hinkelmann, K., & Kempthorne, O. (2007). Design and analysis of experiments, volume 1: Introduction to experimental design (Vol. 1). John Wiley & Sons.
3. Wu, C. J., & Hamada, M. S. (2011). Experiments: planning, analysis, and optimization. John Wiley & Sons.
4. Dean, A., & Voss, D. (Eds.). (1999). Design and analysis of experiments. New York, NY: Springer New York.

E-Resources:

http://www.ru.ac.bd/stat/wp-content/uploads/sites/25/2019/03/502_06_Montgomery-Design-and-analysis-of-experiments-2012.pdf

COs – POs Mapping matrix for STA419/6.0STA09: Design and Analysis of Experiments (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	2	2	3	1	3
CO-2	3	3	3	1	3
CO-3	3	3	3	1	3
CO-4	2	3	2	1	3
CO-5	3	3	2	1	3
Total	**13**	**14**	**13**	**5**	**15**
Average	**2.6**	**2.8**	**2.6**	**1**	**3.0**

Semester III

Course Name: Multivariate Time Series Analysis and Forecasting		Course Code : STA511/6.5STA01
Teaching Scheme	**Examination Scheme**	**Credit Allotted: 04**
Theory: 3 hours/ week	End Semester Examination: 60 Marks	**Course Type: Core**
Practical: 2 hours	Internal Assessment: 20 + 20 Marks	
	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Linear model
2. Linear Algebra
3. Basic of stochastic process

Course Objective:

1. The main purpose is to teach the multivariate time series modeling and the concept of forecasting and future planning.

Course Outcomes: After completion of this course student will able to

1. Understand the concepts of stationarity of a multiple time series and solve related problems.
2. Understand the theory related to multivariate time series models and fit an appropriate time series model for the data.
3. Understand the theory related to multivariate time series model VAR(1) and analyze data using VAR(1) models.
4. Understand the theory related to multivariate time series model VECM and analyze data by using this model.
5. Generate reasonable forecast values and make concise decisions based on forecasts obtained.

Course Content:

Unit No.	Unit Contents	No. of Hrs
1.	Overview of Univariate time series analysis, Multivariate time series, definition, Multivariate Time series: Introduction, Cross covariance, and correlation matrices, testing of zero cross correlation. Introduction of Vector Moving Average (VMA), Vector Autoregressive (VAR) and Vector Autoregressive Moving Average (VARMA).	15
2.	Vector autoregressive (VAR): Introduction, Model Structure, Assumptions and Properties. Structural analysis of with VAR, Estimation of VAR (1), Testing for Causality.	15
3.	Vector error correction model, estimating VECMs, Testing of Granger- Causality, Impulse Response analysis, Lag Selection, model diagnostics.	10
4.	Forecasting, Basic steps in foresting, forecasting tools, forecasting resources, forecasting methods. Forecasting measures. Advance forecasting models (AR, MA, ARMA, ARIMA, ARCH, GARCH, VAR, Panel VAR), problem and challenges with long term forecast, Judgmental forecasting and adjustment. Use of forecasting method in practice.	20

Reference/ Text Books:

1. Box, G. E., Jenkins, G. M., Reinsel, G. C., & Ljung, G. M. (2015). Time series analysis: forecasting and control. John Wiley & Sons.
2. Chatfield, C. (2003). The analysis of time series: an introduction. Chapman and hall/CRC.
3. Tsay, R. S. (2005). Analysis of financial time series. John wiley & sons.

4. Tsay, R. S. (2013). Multivariate time series analysis: with R and financial applications. John Wiley & Sons.
5. Montgomery, D. C., Johnson, L. A., & Gardiner, J. S. (1990). Forecasting and time series analysis. McGraw-Hill Companies.
6. Chatfield, C. (2000). Time-series forecasting. Chapman and Hall/CRC.
7. Brockwell, P. J., & Davis, R. A. (Eds.). (2002). Introduction to time series and forecasting. New York, NY: Springer New York.
8. Cryer, J. D., & Chan, K. S. (2008). Time series analysis: with applications in R (Vol. 2). New York: Springer.

COs – POs Mapping matrix for STA511/6.5STA01: Multivariate Time Series Analysis and Forecasting
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	2	1	3
CO-2	3	3	3	1	3
CO-3	3	3	3	1	3
CO-4	3	3	3	1	3
CO-5	3	3	3	1	3
Total	**15**	**15**	**14**	**5**	**15**
Average	**3**	**3**	**2.8**	**1**	**3**

Course Name: Multivariate Analysis		**Course Code: STA512/6.5STA02**
Teaching Scheme	**Examination Scheme**	**Credit 04**
Theory: 3 hrs/ week	CIA I & II = 20+20 marks ESE: 60 Marks	
Practical: 2 hrs/ week	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Probability and probability distributions
2. Statistical Inference
3. Linear Algebra and linear model

Course Objective: After successfully completing this course, students should ordinarily expect to be able to:

1. Understand the main features of multivariate data.
2. Understand the characteristics of multivariate quantitative research
3. Understand the principles and characteristics of multivariate statistical techniques and methods efficiently and effectively.

Course Outcomes: After completion of this course student will able to

1. Describe basics of multivariate data and understand properties of multivariate normal distribution
2. Describe Wishart distribution, applications of Hotelling's T^2 statistics and Mahalanobis D^2 statistic.
3. Implement discriminant analysis, classification problems, principal components analysis, and canonical correlation analysis effectively.
4. Demonstrate knowledge and understanding of the basic idea behind factor analysis and cluster analysis effectively.
5. Perform classification of multivariate data.

Course Content:

Unit No.	**Unit Contents**	**No. of Hrs**
1.	Multivariate distribution function, marginal and conditional distribution, sample mean vector, sample dispersion matrix, correlation matrix, covariance matrix, exercises. Multivariate normal distribution and its properties, random sampling from multivariate normal distribution, maximum likelihood estimators of parameters, distribution of sample mean vector, exercises.	20
2.	Wishart distribution and its properties. Hotelling's T^2 and its applications. Hotelling's T^2 statistic as a generalization of square of Student's statistic. Distance between two populations, Mahalnobis D2 statistic and its relation with Hotelling's T^2 statistic, Distribution of multiple correlation coefficients, their maximum likelihood estimators (MLE). exercises.	15
3.	Discriminant analysis, classification problem, exercises.	10
4.	Principle component analysis, Factor Analysis, Canonical correlation, Cluster Analysis, Exercises.	15

Reference/ Text Books:

1. Anderson, T. W. (1984): Introduction to Multivariate Analysis, John Wiley
2. Fang, K., Kotz, S., Ng K. W. (1990): Symmetric Multivariate and Related Distributions, Chapman and Hall
3. Härdle, W. K. and Simar, L. (2012): Applied Multivariate Statistical Analysis, Springer, New York
4. Johnson, R.A. and Wichern, D.W. (2007): Applied Multivariate Statistical Analysis, 6th Ed.,

Pearson Education.

5. Kshirsagar, A. M. (1983): Multivariate Analysis, Marcel Dekker
6. Manly, B. F. J., (2004): Multivariate Statistical Methods - A primer, Chapman and Hall / CRC Florida
7. Morrison, D.F. (1990): Multivariate Statistical Methods, McGraw Hill Co.
8. Timm, N. H. (2002): Applied Multivariate Analysis, Springer, New York

E-Resources:

1. https://onlinecourses.swayam2.ac.in/cec20_ma17/preview

COs – POs Mapping matrix for STA512/6.5STA02: Multivariate Analysis (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	2
CO-2	3	3	2	1	3
CO-3	3	3	3	1	3
CO-4	3	3	2	1	3
CO-5	2	3	3	1	3
Total	**14**	**14**	**11**	**5**	**14**
Average	**2.8**	**2.8**	**2.2**	**1**	**2.8**

Course Name : Survival Analysis		**Course Code: STA513/6.5STA03**
Teaching Scheme	**Examination Scheme**	**Credit : 04**
Theory: 3 hrs/ week Practical: 2 hrs/week	CIA I & II = 20+20 marks ESE: 60 Marks Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Distribution theory

Course Objective:

The main objective of this paper is to introduce different concepts and applications of survival analysis.

Course Outcome:

Upon successful completion of this course, the student will be able to:

1. Understand the need of life time distributions and their properties.
2. Identify the different type of censoring.
3. Estimate parameters in presence of censoring.
4. Implement different parametric and nonparametric estimators for estimating survival function.
5. Analyze the lifetime event data.

Course Content

Unit No.	**Unit Contents**	**No. of Hrs**
1	Survival Characteristics and Parametric Models: Survival function, quantiles, hazard rate, cumulative hazard function, and mean residual life, Parametric models for study of event time data: Exponential, Weibull, extreme value, gamma, Pareto, logistic, log-logistic, normal, log–normal and mixture models - their survival characteristics.	**15**
2	Parametric Inference: Longitudinal studies. Censoring mechanisms- type I, type II and left right, Progressive censoring and interval censoring. Likelihood function under censoring and estimation. Tests based on LR, MLE.	**15**
3	Nonparametric Inference: Actuarial and Kaplan–Meier estimators. Treatment of ties. Self-consistency property and asymptotic properties of K–M estimator (statement). Point wise confidence interval for S(t). Nelson-Aalen estimator of cumulative hazard function and estimation of S(t) based on it. Two–sample methods. Comparison of survival functions: Log rank and Tarone-Ware tests.	**15**
4	Semi-parametric Inference: Explanatory variables- factors and variates. Cox proportional hazards model. The partial likelihood and estimation of regression coefficients and their standard errors. Breslow's estimator, Statement of asymptotic properties of the estimator. Confidence interval for regression coefficients. Wald, Rao and likelihood tests for β. Accelerated life model. Model selection criteria and comparison of nested models (-2logL, AIC, BIC). Using information on prognostic variables in a competing risks model. Concept of frailty. Introduction to various frailty models and its applications.	**15**

Reference

1. Cox, D.R. and Oakes, D. (1984). Analysis of Survival Data, Chapman and Hall.
2. Deshpande, J.V. and Purohit S.G. (2005). Life Time Data: Statistical Models and Methods, Word Scientific.
3. Duchateau, L. and Johnson, P. (2008). The Frailty Model. Springer: New York.
4. Gross A.J. and Clark, V. A. (1975) Survival Distributions: Reliability Applications in the Biomedical Sciences, John Wiley and Sons.
5. Hanagal, D. D. (2011). Modeling Survival Data Using Frailty Models. CRC Press: New York.
6. Wienke, A. (2011). Frailty Models in Survival Analysis, CRC Press: New York.

COs – POs Mapping matrix for STA513/6.5STA03: Survival Analysis
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	2
CO-2	3	2	2	1	2
CO-3	3	3	3	1	3
CO-4	3	3	3	1	3
CO-5	2	3	3	1	3
Total	**14**	**13**	**12**	**5**	**13**
Average	**2.8**	**2.6**	**2.4**	**1**	**2.6**

Semester IV

Course Code :	**STA 531/6.5STA81**
Course Name :	**Major Research Project (in Industry or in Academia)**
Credits :	**20**

Course Objectives:

1. To expose students to real-world research problems in industry or academia using statistical methods.
2. To develop the ability to design, plan, and execute an independent research project.
3. To strengthen skills in data collection, statistical analysis, and interpretation using appropriate software tools.
4. To enhance problem-solving, critical thinking, and scientific reasoning abilities.
5. To build professional communication skills through technical report writing and oral presentation.

Course Outcome:

Upon successful completion of this course, the student will be able to:

1. Identify a real-world research problem and formulate clear statistical objectives.
2. Design and implement an appropriate methodology for data collection and analysis.
3. Apply statistical tools and software to analyze real data and interpret results scientifically.
4. Work independently and collaboratively to manage and execute a long-term research project.
5. Communicate research findings effectively through a written report and oral presentation.

Guidelines for project

- **Project duration:** Students may start preliminary work related to their project after third semester.

- **Project Guide:** Teachers from the Department of Statistics and/or organization where student is going to visit for field work or training. For outside organization, there will be one internal teacher who monitor the progress of the student. Each project student have to work 20 hours per week in the department or work place (in case of industrial) throughout the IV semester.

- **Project Topic:** Students in consultation with the guide will decide project topic. The modification on the title may be permitted after the pre-presentation as advised during the seminar in consultation with the supervisor. Project work may be carried out in a group of students depending upon the depth of fieldwork/problem involved.

- **Project report:** Project report should be submitted in typed form in hard bound within the time as stipulated by the Department.

- Project Evaluation: The evaluation of Major Project will comprise of two components Internal and External.

Internal Component will further comprise of two subcomponents

- Continuous evaluation of the work – 30 Marks awarded by supervisor
- Project report and final presentation – 20 marks by all faculty member of the department.

External Component

The External expert from outside University/Institute will conduct a Viva-voce and final presentation of all the students and award a maximum of 50 marks.

COs – POs Mapping matrix for STA 531/6.5STA81: Major Research Project (in Industry or in Academia)
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	2	1	2
CO-2	3	3	3	1	3
CO-3	3	3	3	1	3
CO-4	2	2	2	3	3
CO-5	2	2	2	3	3
Total	**13**	**12**	**12**	**9**	**14**
Average	**2.6**	**2.4**	**2.4**	**1.8**	**2.8**

List of Electives for Semester II

Course Name: National Development Statistics (Elective)		**Course Code: STA481/6.0STA31**
Teaching Scheme	**Examination Scheme**	**Credit 03**
Theory: 3 hrs/ week	CIA: 20+20 Marks ESE: 60 Marks Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of
Normal, Chi-square, t, and F distributions, t-test

Objective:
The main objective is to make individual understand the significance and role of statistics in national development.

Learning Outcome:
Upon successful completion of this course, the student will be able to:

1. Understand the concept of Economic development parameters.
2. Differentiate the population growth of developed and developing countries.
3. Apply different techniques of poverty measurement.
4. Know various institutions responsible for the collection of data in India.
5. Understand various issues in the measurement of poverty.

Course Content

Unit No.	**Unit Contents**	**No. of Hrs**
1	Economic development: Growth in per capital income and distributive justice, Indices of development, Human Development index, quality of life. Estimation of national income-product approach, income approach and expenditure approach	12
2	Population growth in developing and developed countries, Population projection using Leslie matrix, Labour force projection.	10
3	Poverty measurement-different issues, measures of incidence and intensity, combined measures e.q. indices due to Kakwani, Sen etc.	13
4	MOSPI- Statistical System of India: NSSO, CSO, NSSTA, NITI Ayoge, Different Institutions and committees are responsible for planning and execution of National Building.	10

Assessment:

CIA	CIA I	Written
	CIA II	Written/Assignment/ Viva/Presentation
ESE	ESE	Written

References

1. Chatterjee, S.K.: Quality of life.
2. Chaubey, P. K.: Poverty Analysis, New Age International (P) Limited, Publishers. New Delhi.
3. Human Development Annual Report.
4. Sen, Amartya.: Poverty and Famines, Oxford University Press.
5. CSO. National Accounts Statistics- Sources and Health.
6. UNESCO: Principles of Vital Statistics Systems.

COs – POs Mapping matrix for STA481/6.0STA31: National Development Statistics
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	2
CO-2	3	2	1	1	2
CO-3	3	3	2	1	3
CO-4	3	1	1	2	3
CO-5	3	2	1	2	3
Total	**15**	**10**	**6**	**7**	**13**
Average	**3**	**2.0**	**1.2**	**1.4**	**2.6**

Course Name: Computer Intensive Statistical Methods (Elective)		**Course Code: STA482/6.0STA32**
Teaching Scheme	**Examination Scheme**	**Credit : 03**
Theory: 2 hrs/ week Practical: 2 hrs/week	CIA: 20+20 Marks ESE: 60 Marks Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Statistical inference
2. Nonparametric inference
3. Regression analysis

Course Objective:

The main objective of this paper is to make students understand computationally intensive methods for doing statistical inference.

Learning Outcome:

Upon successful completion of this course, the student will be able to:

1. Understand the necessity of resampling methods.
2. Recall missing data imputation techniques to impute missing values.
3. Develop programing codes for computationally intensive methods.
4. Evaluate different statistical algorithms using cross validation.
5. Apply various Bayesian techniques to analyze real life problems.

Course Content :

Unit No.	**Unit Contents**	**No. of Hrs**
1	Resampling Techniques: Resampling paradigms, bias-variance trade-off. Bootstrap methods, estimation of sampling distribution, confidence interval, variance stabilizing transformation. Jackknife and cross-validation. Jackknife in sample surveys. Jackknife in regression under heteroscedasticity. Permutation tests.	11
2	Missing Values and Imputations Techniques: Missing values and types of missingness, imputations methods for missing values, single and multiple imputations. EM Algorithm and Applications: EM algorithm for incomplete data, EM algorithm for mixture models, EM algorithm for missing values, stochastic EM algorithm.	11
3	Smoothing techniques: Kernel estimators, nearest neighbor estimators, orthogonal and local polynomial estimators, wavelet estimators. Splines. Choice of bandwidth and other smoothing parameters.	11
4	Bayesian computing, Markov Chain Monte Carlo. Simulation using MCMC, MCMC methods for missing values.	12

Reference/Text Books:

1. Buuren, Stef van (2012). Flexible Imputation of Missing Data. Chapman and Hall.
2. Chihara, L. and Hesterberg, T. (2011) Mathematical Statistics with Resampling and R. Wiley.
3. Davison, A.C. and Hinkley, D.V. (1997) Bootstrap methods and their Applications. Chapman and Hall.
4. Efron, B. and Tibshirani. R.J. (1994); An Introduction to the Bootstrap. Chapman and Hall.
5. Gilks, W. R., Richardson, S., and Spiegelhalter, D. (eds.) (1995) Markov Chain Monte Carlo in Practice. Chapman and Hall.
6. Good, P. I. (2005) Resampling Methods: A Practical Guide to Data Analysis. Birkhauser Bosel.
7. Hanson T. E. (2011). Bayesian Ideas and Data Analysis: An Introduction for Scientists and Statisticians, Chapman Hall.
8. Jim, A. (2009). Bayesian Computation with R, 2nd Edn, Springer.
9. Kennedy W. J. Gentle J. E. (1980) Statistical computing. Marcel Dekker.
10. McLachlan, G.J. and Krishnan, T. (2008) The EM Algorithms and Extensions. Wiley.
11. Shao J. and Tu, D. (1995); The Jackknife and the Bootstrap. Springer Verlag.

COs – POs Mapping matrix for STA482/6.0STA32: Computer Intensive Statistical Methods (1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	3	2	1	2
CO-2	3	2	3	1	3
CO-3	2	3	2	1	3
CO-4	3	3	3	1	3
CO-5	3	3	3	1	3
Total	**14**	**14**	**13**	**5**	**14**
Average	**2.8**	**2.8**	**2.6**	**1**	**2.8**

Course Name: Machine Learning (Elective)		**Course Code: STA 484/6.0STA33**
Teaching Scheme	**Examination Scheme**	**Credit :3**
Theory: 2 hrs/ week	CIA: 20+20 Marks	
Practical: 2 hrs/week	ESE: 60 Marks	
8	Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

(i) Linear algebra
(ii) Multivariate statistics
(iii) Regression

Course Objective:

1. The objective is to familiarize the audience with some basic learning algorithms and techniques and their applications, as well as general questions related to analyzing and handling large data sets.
2. The emphasis will be on machine learning algorithms and applications, with some broad explanation of the underlying principles.
3. To develop the basic skills necessary to pursue research in machine learning.
4. To develop the design and programming skills that will help learner to build intelligent, adaptive artifacts.

Course Outcomes:

Upon successful completion of this course, the student will be able to:

1. Understand different types of learning methods.
2. Apply different prediction models to real life data.
3. Apply different clustering algorithms to real life data.
4. Compare different machine learning algorithms.
5. Perform classification of massive data using appropriate machine learning algorithms.

Course Content:

Unit No.	**Unit Contents**	**No. of Hrs**
1	Introduction to machine learning, learning methods, supervised learning, unsupervised learning, data preprocessing, problem of classification, logistic regression as a classifier, k-nearest neighbor classifier, naïve Bayes classifier, artificial neural networks, classification trees, support vector machines, linear discriminant analysis, multiclass classification. Imbalance data and related problems. Accuracy measures, model validation, k-fold cross validation.	20
2	Clustering: K-Means, hierarchical clustering-agglomerative, divisive, distance measures, density-based clustering – DBscan, spectral clustering. Selection of appropriate number of clusters, CLARA, DENCLUE..	10
3	Ensemble Methods: Boosting-adaboost, gradient boosting, bagging - simple methods, random forest, hyper parameter tunning.	10
4	Dimensionality Reduction: Principal component analysis, t-SNE, Association rule mining.	5

Reference/Text Books:

1. Pattern Recognition and Machine Learning. Christopher Bishop.
2. Machine Learning. Tom Mitchell.
3. Pattern Classification. R.O. Duda, P.E. Hart and D.G. Stork.
4. Data Mining: Tools and Techniques. Jiawei Han and Michelline Kamber.
5. Elements of Statistical Learning. Hastie, Tibshirani and Friedman. Springer.
6. Manifold learning theory and applications (Vol. 434). Ma, Y., & Fu, Y. Boca Raton: CRC press.

COs – POs Mapping matrix for STA 484/6.0STA33: Machine Learning
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	2
CO-2	3	3	1	1	3
CO-3	2	3	2	1	3
CO-4	3	3	2	1	3
CO-5	2	3	3	1	3
Total	**13**	**14**	**9**	**5**	**14**
Average	**2.6**	**2.8**	**1.8**	**1**	**2.8**

LIST OF ELECTIVES FOR SEMESTER III

Couse Name: Econometrics (Elective)		**Course Code: STA581/6.5STA31**
Teaching Scheme	**Examination Scheme**	**Credit Allotted : 3**
Theory: 3 hrs/ week	CIA: 20+20 Marks ESE: 60 Marks Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Correlation regression
2. Multivariate data analysis

Course Objective:

The main objective is to introduce branch which is an integration of mathematics, statistics, and economics used to deal with econometric models.

Course Outcomes:

Upon successful completion of this course, the student will be able to:

1. Understand the properties and problems of econometric models.
2. Recall various estimation and testing of hypothesis procedures in econometric models.
3. Understand the concept of panel data models.
4. Identify the fixed and random effect models.
5. Apply Simultaneous Equation Models to analyse the economic data.

Course Content :

Unit No.	**Unit Contents**	**No. of Hrs**
1	Introduction of Econometrics, Multiple Linear Regression Model, Model with non-spherical disturbances, Test of Auto-correlation, restricted regression estimator, Errors in variables, Dummy variables, Logit and Probit Models. Problem of heteroscedasticity, general Gauss-Markov theorem, generalized weighted least square estimators,	**15**
2	Seemingly unrelated regression equation (SURE) model and its Estimation, Simultaneous equations model, concept of structural and reduced forms problem of identification, rank and order condition of identifiability.	**15**
3	Methods of estimation of simultaneous equation model: indirect least squares, two stage least squares and limited information maximum likelihood estimation, idea of three stage least squares and full information maximum likelihood estimation, and prediction	**10**
4	Panel data models: Estimation in fixed and random effect models, Panel data unit root test	**05**

Reference/Text Books:

1. Apte, P.G.: Text books of Econometrics, Tata McGraw Hill.
2. Gujarathi, D.: Basic Econometrics; McGraw Hill.
3. Johnston, J.: Econometrics Methods. Third edition, McGraw Hill.
4. Srivastava, V.K. and Giles D. A. E.: Seemingly unrelated regression equations models, Marcel Dekker.
5. Ullah, A. and Vinod, H.D.: Recent advances in Regression Methods, Marcel Dekker.

COs – POs Mapping matrix for STA581/6.5STA31: Econometrics
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	2	2	2
CO-2	2	3	3	1	2
CO-3	3	2	2	1	2
CO-4	2	3	2	1	2
CO-5	2	3	3	1	3
Total	**12**	**13**	**12**	**6**	**11**
Average	**2.4**	**2.6**	**2.4**	**1.2**	**2.2**

Course Name : Discrete Data Analysis (Elective)		**Course Code: STA582/6.5STA32**
Teaching Scheme	**Examination Scheme**	**Credit 03**
Theory: 3 hrs/ week	CIA: 20+20 Marks ESE: 60 Marks Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

3. ANOVA
4. Regression Analysis

Course Objective:

The main objective of this course is to introduce discrete data analysis.

Course Outcomes:

Upon successful completion of this course, the student will be able to:

1. Understand categorical data and its related inferences.
2. Understand fitting of generalized linear models and its analysis using goodness of fit criterion.
3. Understand the utilization of suitable link function which will help them to apply generalized linear models.
4. Analyze categorical data using logistic regression framework.
5. Apply Poisson and Negative Binomial regression to real life data sets.

Course Content :

Unit No.	**Unit Contents**	**No. of Hrs**
1	**Log linear model**: Log linear model for two and three dimensional contingency tables: Interpretation of parameters, comparison with ANOVA and regression. ML estimation of parameters, likelihood ratio tests for various hypotheses including independence marginal and conditional independence, partial association, models with quantitative levels.	**15**
2	**Generalized linear models**: concept of generalized linear model, Link function, ML estimation, Quasi-likelihood estimation, large sample tests about parameters, goodness of fit, analysis of deviance. Residual analysis, types of residuals: raw, Pearson, deviance, Anscombe, quantile; residual plots. Variable selection: AIC and BIC.	**15**
3	**Regression models for count data,** Poisson regression, and problem of over dispersion, Quasi-likelihood, NB1, NB2 models. Introduction to generalized mixed linear models.	**15**

Reference/Text Books:

1. Yuvonne M. Bishop, Stephen E. Fienberg, Paul W. Holland (1975): Discrete Multivariate Analysis: Theory and Practice
2. Hosmer D.W. and Lemeshow S. (2000): Applied Logistic regression, 2nd ED. Wiley New York.
3. Agesti A. (1990): Categorical Data Analysis. Wiley, New York.
4. R.Christensen (1997) Log-Linear Models and Logistic Regression, Springer. New York.
5. Hilbe, J. (2011): Negative Binomial regression, Cambridge University, Press, 2nd Edition.
6. McCulloch, C. E., & Searle, S. R. (2004). Generalized, linear, and mixed models. John Wiley & Sons.

COs – POs Mapping matrix STA582/6.5STA32: Discrete Data Analysis
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	2	1	2
CO-2	2	3	3	1	3
CO-3	2	3	2	1	2
CO-4	2	3	3	1	3
CO-5	2	3	3	1	3
Total	**11**	**14**	**13**	**5**	**13**
Average	**2.2**	**2.8**	**2.6**	**1**	**2.6**

Course Name : Nonparametric Statistics		Course Code : STA583/6.5STA33
Teaching Scheme	**Examination Scheme**	**Credit 03**
Theory: 3 hours/ week	CIA: 20+20 Marks ESE: 60 Marks Total: 100 Marks	

Course Pre-requisites: Student must have knowledge of

4. Parametric inference
5. Regression analysis
6. Analysis of variance

Course Objective:

1. To broaden mind in terms of thinking about data and inference in a nonparametric way.
2. To introduce useful nonparametric methods that you can apply while analyzing data
3. To familiarize with important topics in nonparametric statistics that you may wish to research.

Course Outcomes: After completion of this course student will able to

1. Understand basic concepts of nonparametric statistics.
2. Recall applications of nonparametric methods for analyzing data from variety areas.
3. Perform and interpret the nonparametric tests for different testing of hypothesis problems.
4. Identify multiple applications where nonparametric approaches are appropriate.
5. Compare the nonparametric methods with different methods.

Course Content:

Unit No.	Unit Content	No. of Hours
1.	Introduction to nonparametric statistics, advantages and disadvantages of nonparametric methods, kernel, U-statistic, one sample testing of hypothesis problem, sign test, signed rank test, two sample testing of hypothesis problem, two-sample U-statistics, Wilcoxon signed rank test, Mann-Whitney test, Wilcoxon signed rank test for paired sample problem.	15
2.	One-way Layout and two-way layout, Kruskal-Wallis test for one-way analysis of variance, multiple comparison procedures, Friedman tests for two-way analysis of variance.	15
3.	Problem goodness of fit, Chi-square goodness of fit test, Kolmogorov-Smirnov one-sample and two sample tests,	07
4.	Problem of density estimation, kernel function, naïve estimator, kernel estimators, nearest neighbour estimators, nonparametric regression, kernel regression, locally weighted regression.	08

Reference Books:

1. Gibbons, J. D., & Chakraborty, S. (2014). *Nonparametric statistical inference*. CRC press.
2. Conover, W. J. (1999). *Practical nonparametric statistics* (Vol. 350). John wiley & sons.
3. Silverman, B. W. (2018). *Density estimation for statistics and data analysis*. Routledge.
4. Montgomery, D. C., Peck, E. A., & Vining, G. G. (2021). *Introduction to linear regression analysis*. John Wiley & Sons.

E-Resources:

http://www.ru.ac.bd/stat/wp-content/uploads/sites/25/2019/03/501_13_Gibbons_Nonparametric_statistical_inference.pdf

https://nptel.ac.in/courses/111102143

COs – POs Mapping matrix STA583/6.5STA33: Nonparametric Statistics
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	1	2
CO-2	2	2	2	1	2
CO-3	2	3	3	1	3
CO-4	2	2	2	1	2
CO-5	2	2	2	1	2
Total	**11**	**11**	**10**	**5**	**11**
Average	**2.2**	**2.2**	**2**	**1**	**2.2**

Course Name: Tools for Data Science (Elective)		**Course Code: STA584/6.5STA34**
Teaching Scheme Theory: 2 hrs/ week Practical: 2 hrs/week	**Examination Scheme** **CIA:** 20+20 Marks **ESE:** 60 Marks Total=100 Marks	**Credit : 3**

Course Pre-requisites: Student must have knowledge of

1. Machine learning, Statistics

Course Objective:

2. To understand and analyze the image and text data.

Course Outcomes: After completion of this course student will able to

1. Visualize data using advance visualization tools.
2. Analyze the image data.
3. Create language models for analyzing text data.
4. Apply machine learning models for image and text data.
5. Build interactive dashboards and visual analytics using advanced visualization tools and Tableau for data-driven insights.

Course Content:

Unit No.	**Unit Contents**	**No. of hrs**
1.	Data Visualization Techniques: ggplot2, Bar plots, Pei chart, Histogram, Boxplot, Boxplot for heavy tailed data, Violin plot, QQ-plot, PP-plot, Gini coefficient, Scatter plot, Bubble plot, Mosaic plots, Bag plot, Heatmap, corrgrams, Generalized pairs plots, Added variable plots, Contour plot, 2D density contour plot. Tablue: Basic reports, learn tablue charts, filters, dashborads.	15
2.	Image processing: Getting Started with images, Basic Operations on Images, Arithmetic Operations on Images, Image Preprocessing: changing colorspaces, geometric transformations, thresholding, smoothing, morphological transformations, gradients, Canny Edge detection, image pyramids, image segmentation with Watershed algorithm, Feature Detection and Description. Image Detection and recognition examples.	15
3.	Text Mining: Introduction to Natural Language Processing (NLP), Natural Language Toolkit (NLTK) in Python. Data Preparation: punctuation removal, stop-words removal, numeric value removal, frequent words removal, rare words removal, spelling correction, tokenization, stemming, lemmatization. Feature Engineering: count vectors as features, Term Frequency-Inverse Document Frequency (TF-IDF), TF-IDF vectors as features, word level TF-IDF, N-Gram level TF-IDF, Character level TF-IDF, world cloud, Inverse Document Frequency, word embedding as features, Text/NLP based features, Topic Models as features, word2vec, sentiment analysis.	15

Reference/Text Books:

1. Healy, K. (2018). Data visualization: a practical introduction. Princeton University Press.
2. Goodfellow, I., Bengio, Y., Courville, A., & Bengio, Y. (2016). Deep learning (Vol. 1). Cambridge: MIT press.
3. Shanmugamani R. (2018). Deep Learning for Computer Vision: Expert techniques to train advanced neural networks using TensorFlow and Keras. "Packt Publishing Ltd"
4. Bird, S., Klein, E., &Loper, E. (2009). Natural language processing with Python: analyzing text with the natural language toolkit. " O'Reilly Media, Inc.".
5. Hardeniya, N., Perkins, J., Chopra, D., Joshi, N., &Mathur, I. (2016). Natural Language Processing: Python and NLTK. Packt Publishing Ltd.
6. Mueller, J. P., &Massaron, L. (2015). Python for data science for dummies. John Wiley & Sons.

COs – POs Mapping matrix STA584/6.5STA34: Tools for Data Science
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	2	2	3	1	3
CO-2	1	3	3	1	3
CO-3	1	3	3	1	3
CO-4	1	3	3	1	3
CO-5	1	2	2	1	3
Total	**6**	**13**	**14**	**5**	**15**
Average	**1.2**	**2.6**	**2.8**	**1**	**3**

Course Name : Bayesian Inference (Elective)		**Course Code: STA585/6.5STA35**
Teaching Scheme	**Examination Scheme**	**Credit Allotted:03**
Theory: 3 hrs/ week	**CIA:** 20+20 Marks **ESE:** 60 Marks Total=100 Marks	

Course Pre-requisites: Student must have knowledge of

1. Probability distributions
2. Statistical inference

Course Objective:

To know Bayesian approach to solve statistical decision problems and use Bayesian techniques for computation.

Course Outcomes:

Upon successful completion of this course, the student will be able to:

1. Distinguish between frequentist and Bayesian approach.
2. Employ prior information for analyse of real life data.
3. Choose appropriate prior distributions.
4. Compute Bayes estimates for the population parameters.
5. Apply Bayesian theory in testing of hypothesis problems.

Course Content:

Unit No.	**Unit Contents**	**No. of hrs**
1	Frequentist vs. epistemic concepts of probability, Bayes's rule, prior and posterior distributions, likelihood, discrete probability examples, simple continuous distributions examples, popular R packages for Bayesian analysis. Bayesian linear regression, choice of priors, interpretation of model parameters, Bayesian inference, credibility intervals, Bayesian generalized regression modeling, examples in MCMC pack and rstanarm.	20
2	MCMC Estimation: MCMC estimation, Gibbs sampling, Hamiltonian Monte-Carlo, main convergence diagnostics, INLA, variational inference.	15
3	Bayes factors, Bayesian Information Criterion (BIC) and Deviance Information Criterion (DIC), WAIC, leave-one-out cross-validation.	10

Reference/Text Books:

1. Berger, J. O. : Statistical Decision Theory and Bayesian Analysis, Springer Verlag.
2. Robert, C.P. and Casella, G. : Monte Carlo Statistical Methods, Springer Verlag.
3. Leonard, T. and Hsu, J.S.J. : Bayesian Methods, Cambridge University Press.
4. Bernando, J.M. and Smith, A.F.M. : Bayesian Theory, John Wiley and Sons.
5. Robert, C.P. : The Bayesian Choice: A Decision Theoretic Motivation, Springer.
6. Gemerman, D. : Markov Chain Monte Carlo: Stochastic Simulation for Bayesian Inference, Chapman Hall.
7. Box, G.P. and Tiao, G. C.: Bayesian Inference in Statistical Analysis, Addison-Wesley.

COs – POs Mapping matrix STA585/6.5STA35: Bayesian Inference
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	3	2	1	2	2
CO-2	2	3	3	1	3
CO-3	2	3	2	1	2
CO-4	2	3	3	1	3
CO-5	2	3	3	1	3
Total	**11**	**14**	**12**	**6**	**13**
Average	**2.2**	**2.8**	**2.4**	**1.2**	**2.6**

Course Name: Optimization Techniques (Elective)	Course Code : STA 586/6.5STA36

Teaching Scheme	Examination Scheme	Credit: 3
Theory: 3 hrs/ week	CIA: 20+20 Marks ESE: 60 Marks Total: 100 Marks	

Pre-requisite:
Operation research, Stochastic processes.

Course Objective:

1. to formulation of the dynamic and integer programming and its solutions
2. to design decision making problem and to find optimal solution
3. to understand the mathematical modeling of a queuing problem and its solution
4. to formulate the inventory and replacement problems and to find its solution

Course Outcomes: After completion of this course student will able to

1. design the dynamic and integer programming problems and its solutions
2. find an optimal strategies and solution of the given decision making problem
3. modeling and find a solution of a given queuing problem
4. understand an inventory and replacement problems
5. use appropriate optimization software/tools to solve real-life operations research problems.

Course Content:

Unit No.	Unit Content	No. of Hrs
1.	Dynamic programming - Bellman's principle of optimality, general formulation. Integer Programming-Modelling using pure and mixed integer programming, Gomory's Cutting Plane Algorithm. Branch and Bound technique. Stochastic Programming.	12
2.	Decision-making in the face of competition, two-person games, pure and mixed strategies, existence of solution and uniqueness of value in zero-sum games, finding solutions in 2x2, 2xm and mxn games. Solution 3x3 game by using simplex procedure.	12
3.	Queuing models – specification 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-Khinchine result.	09
4.	Inventory Models– Analytical structure, Deterministic and Probabilistic Models, ABC Classification, EOQ analysis and extensions allowing quantity discounts and shortages. Replacement problems: Block and age replacement policies. Replacement of items that fail gradually and stochastically.	12

Reference Books:

1. F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, 9th Ed., Tata McGraw Hill, Singapore, 2009.
2. Hadley, G: (2002) : Linear Programming, Narosa Publications
3. Hamdy A. Taha, Operation research-An Introduction, Prentice Hall, 8th Ed., 2007
4. J. K. Sharma, Operations Research Theory & Applications, Macmillan India Limited.
5. Kanti Swarup, Gupta, P.K. and Manmohan (2007): Operations Research, 13th Edition, Sultan Chand and Sons
6. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, Linear Programming and Network Flows, 2nd Ed., John Wiley and Sons, India, 2004
7. Ravindran, A, Phillips, D.T., Solberg, J.J.(2005): Operations Research- Principles and Practice, John Wiley & Sons
8. Taha, H. A. (2007): Operations Research: An Introduction, 8th Edition, Prentice Hall of India
9. V. K. Kapoor, Operations Research, Sultan Chand & Sons

COs – POs Mapping matrix STA586/6.5STA36: Optimization Techniques
(1-low, 2-medium, 3-high)

PO→ CO ↓	PO1	PO2	PO3	PO4	PO5
CO-1	2	3	3	1	3
CO-2	2	3	3	1	3
CO-3	2	3	3	1	3
CO-4	2	2	2	1	3
CO-5	1	3	3	1	3
Total	**9**	**14**	**14**	**5**	**15**
Average	**1.8**	**2.8**	**2.8**	**1**	**3**

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