Rayat Shikshan Sanstha's

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YASHAVANTRAO CHAVAN INSTITUTE OF SCIENCE, SATARA

(AN AUTONOMOUS COLLEGE)

Reaccredited by NAAC with 'A+' Grade

Bachelor of Science

Part - III

STATISTICS

Syllabus

Choice based credit system syllabus

(To be implemented from academic year 2023-24)

Department of Statistics

B.Sc. Part – III

Revised B.Sc. Part – III Statistics (CBCS) Syllabus w.e.f. June 2023

1. Structure of the Syllabus:

B.Sc. III Semester – V

Paper Title	Theory			Practical		
	Paper Code	Lectures Per Week	Credits	Paper Title	Lectures Per Week	Credits
Compulsory Papers						
Probability Distribution -I	BST 501	3	2	BSP 508	10	4
Statistical Inference -I	BST 502	3	2			
Operation Research	BST 503	3	2			
Elective Papers (Any One)						
Design of Experiment	BST 504	3	2	BSP 509 + Project	10	4
Demography and Vital Statistics	BST 504					
Data Mining	BST 504					
Numerical Skills in Computational Statistics	SECCST 507	2	1	BSP 510	4	1

B.Sc. III Semester – VI

Paper Title	Theory			Practical		
	Paper Code	Lectures Per Week	Credits	Paper Title	Lectures Per Week	Credits
Compulsory Papers						
Probability Distribution -II	BST 601	3	2	BSP 608	10	4
Statistical Inference -II	BST 602	3	2			
Industrial Statistics	BST 603	3	2			
Elective Papers (Any One)						
Sampling Theory	BST 604	3	2	BSP 609 + Project	10	4
Survey Sampling and Official Statistics	BST 604					
Reliability Theory	BST 604					
Entrepreneurship development in Statistics	SECCST607	2	1	BSP 610	4	1

Equivalence

Semester V

Old		New	
Course Code	**Title of the Course**	**Course Code**	**Title of the Course**
BST 501	Probability Distribution -I	BST 501	Probability Distribution -I
BST 502	Statistical Inference -I	BST 502	Statistical Inference -I
BST 503	Operation Research	BST 503	Operation Research
BST 504	Design of Experiment	BST 504	Design of Experiment
BST 504	Demography and Vital Statistics	BST 504	Demography and Vital Statistics
BST 504	Data Mining	BST 504	Data Mining
SECCST 507	Numerical Skills in Computational Statistics	SECCST 507	Numerical Skills in Computational Statistics
BSP 508	Practical Paper - I	BSP 508	Practical Paper - I
BSP 509	Practical Paper - II	BSP 509	Practical Paper - II
BSP 510	Practical Paper - III	BSP 510	Practical Paper - III

Semester VI

Old		New	
Course Code	**Title of the Course**	**Course Code**	**Title of the Course**
BST 601	Probability Distribution -II	BST 601	Probability Distribution -II
BST 602	Statistical Inference -II	BST 602	Statistical Inference -II
BST 603	Industrial Statistics	BST 603	Industrial Statistics
BST 604	Sampling Theory	BST 604	Sampling Theory
BST 604	Survey Sampling and Official Statistics	BST 604	Survey Sampling and Official Statistics
BST 604	Reliability Theory	BST 604	Reliability Theory
SECCST 607	Entrepreneurship development in Statistics	SECCST 607	Entrepreneurship Development Program
BSP 608	Practical Paper - V	BSP 608	Practical Paper - VIII
BSP 609	Practical Paper – VI	BSP 609	Practical Paper - IX
BSP 610	Practical Paper - VII	BSP 610	Practical Paper - X

Semester – V

Course IX BST 501 PROBABILITY DISTRIBUTION - I

Course Objectives: Students will be able to

1. Understand the concept of probability and probability distribution.
2. Differentiate between univariate probability distribution and truncated probability distribution.
3. Compute the distribution of the transformed random variable.
4. Apply univariate continuous probability distribution to real-life data

Credits (Total Credits 2)	SEMESTER-V BST 501 PROBABILITY DISTRIBUTION - I	No. of hours per unit/credits
UNIT - I	**Continuous Univariate Distributions**	**(15)**
	1.1 Laplace(Double Exponential) Distribution: P.d.f. with parameters(μ, λ), Nature of the probability curve, Distribution function, quartiles, m. g. f., mean, variance, moments, β_1, β_2, γ_1 and γ_2 Laplace distribution as the distribution of the difference of two i. i. d. exponential variates with parameter θ , Real life examples and problems **1.2 Lognormal Distribution:** P.d.f. with parameters(μ,σ^2) ,Nature of the probability curve, mean, variance, median, mode, moments, β_1, β_2, γ_1 and γ_2 coefficients, Relation with N(μ,σ^2) , Real life examples and problems. **1.3 Cauchy Distribution:** P.d.f. with parameters(μ,λ), nature of the probability curve, distribution function, quartiles, non-existence of moments, additive property for twoindependent Cauchy variates (statement only), statement of distribution of the sample mean, relationship with uniform and Student's 't' distribution, distribution of X/Y where Xand Y are i.i.d. N(0,1), Real life examples and problems.	
UNIT - II	**Univariate Probability Distributions**	**(8)**
	2.1 Logistic distribution: P.d.f. with parameters(μ , σ),c.d.f., mean, mode, variance, skewness using mode, applications. **2.2 Pareto distribution:** P.d.f. with parameters (α, β),mean, variance, mode, skewness using mode, applications. **2.3 Power series distribution:** P.m.f. mean, mode, variance, Binomial, Poisson, Geometric and negative binomial distribution as particular cases of power series distribution.	
UNIT - III	**Truncated Distributions**	**(10)**

	3.1 Truncated distribution as conditional distribution, truncation to the right, left and onboth sides. **3.2** Binomial distribution B(n, p) left truncated at X = 0(value zero not observable), its p.m.f mean, variance. **3.3** Poisson distribution P(m), left truncated at X= 0(value zero not observable),its p.m.f.,mean and variance. **3.4** Normal distribution N(μ,σ^2) truncated i. To the left below a ii. To the right above b iii. To the left below a and to the right above b, its p.d.f. And mean. **3.5** Exponential distribution with parameter θ left truncated below a , its p.d.f. mean and variance. **3.6** Real-life examples and problems.	
UNIT - IV	**Mixtures Distribution and Transformation**	**(12)**
	4.1 Mixtures of probability distributions, decomposition of mixture type c.d.f. into discrete and continuous c.d.f.'s. **4.2** Transformations of univariate random variables, Convolutions, compound distributions. Probability Integral transformation.	

Course Outcomes: Students should be able to

1. Understand Logistic distribution, Pareto distribution, and Multinomial distribution.
2. Identify Truncated Distribution and solve the problem.
3. Solve examples of Univariate Continuous Probability Distributions.
4. Decompose of mixture type c.d.f.into discrete and continuous c.d.f.' s.

Reference Book:

1. Cramer H. , Mathematical Methods of Statistics, Asia Publishing House, Mumbai, 2005
2. Mood, A. M., Gray bill K, Bose. D. C , Introduction to Theory of Statistic, Mc-Graw Hiil Series, 2005.
3. Lindgren B.W, Statistical Theory (Third Edition), Collier Macmillan International Edition, Macmillan Publishing Co. Inc. New York, 2004.
4. Hogg, R. V. and Craig A. T., Introduction to Mathematical Statistics (Third Edition), Macmillan Publishing Company, 2000.
5. Sanjay Arora and Bansi Lal, New Mathematical Statistics (First Edition), Satya Prakashan, New Market, New Delhi, 1989.
6. Gupta S. C and Kapoor V. K., Sultan Chand and Sons, Fundamentals of Mathematical Statistics,
7. Rohatgi V. K., An Introduction to Probability Theory and Mathematical Statistics, Wiley
8. Feller. W, An Introduction of Probability Theory and its Applications, Wiley Eastern Ltd .Mumbai

Course X BST 502 STATISTICAL INFERENCE - I

Course Objectives: Students will be able to

1. Understand the concept of point estimation.
2. Obtain an unbiased estimator for the parameters of the distribution.
3. Apply various methods of point estimation of parameter
4. Estimate unknown parameters by point and interval estimation method.

Credits (Total Credits 2)	**SEMESTER-V** **BST 502** **STATISTICAL INFERENCE - I**	**No. of hours per unit/credits**
UNIT - I	**Point Estimation**	**(5)**
	1.1: Notion of a parameter, parameter space, general problem of estimation, estimating an unknown parameter by point and interval estimation. 1.2: Point estimation: Definition of an estimator, statistic & its S.E., distinction between estimator and estimate, illustrative examples	
UNIT - II	**Properties of Estimator**	**(18)**
	2.1 Properties of estimator: Unbiased estimator , biased estimator, positive and negative bias, examples of unbiased and biased estimators. Proofs of the following results regarding the unbiased estimators: (a) Two distinct unbiased estimators of $\Omega(\theta)$ give rise to infinitely many unbiased estimators of $\Omega(\theta)$ (b) If T is unbiased estimator of θ then Ω (T) is an unbiased estimator of $\Omega(\theta)$ provided Ω (.) is a linear function. Sample variance is a biased estimator of the population variance. Illustration of unbiased estimator for the parameter and parametric function. 2.2 Minimum Variance Unbiased Estimator (MVUE) and Uniformly Minimum Variance Unbiased Estimator (UMVUE), RB and LS uniqueness of UMVUE whenever it exists. Illustrative examples. 2.3 Sufficiency: Concept of sufficiency, definition of sufficient statistic through (i) conditional distribution (ii) Neyman factorization criterion. Pitman Koopman form and sufficient statistic. Proof of the following properties of sufficient statistic: If T is sufficient forθ then Ω (T) is also sufficient for θ provided Ω (.) ibjective function. If T is sufficient for θ then T is sufficient for $\Omega(\theta)$. 2.4 Fisher information function: Definition of information function, amount ofnformation contained in a sample. Statement regarding equality of the information in (x1, x2, ..., xn) and in a	

	sufficient statistic T, concept of minimal sufficient statistic. With illustrations to exponential family. 2.5 Statement and proof of Cramer Rao inequality. Definition of Minimum Variance Bound Unbiased Estimator (MVBUE) of $\Omega(\theta)$. Proof of the following results: If MVBUE exists for è then MVBUE exists for$\Omega(\theta)$, if Ω (.) is a linear function. If T is MVBUE for θ then T is sufficient for è. Examples and problems. 2.6 Relative efficiency of T1 with respect to T2, where T1 and T2 are unbiased estimators. Use of mean square error to modify the above definition for biased estimator. 2.7 Consistency : Definition, proof of the following: Sufficient condition for consistency, If T is consistent for θ and Ω (.) is a continuous function then Ω (T) is consistent for $\Omega(\theta)$ Illustrative examples.	
UNIT - III	**Methods of Estimation**	**(11)**
	3.1: Definition of likelihood function as a function of the parameter θ for a random sample from discrete and continuous distributions. Illustrative examples. 3.2 : Method of maximum likelihood estimator ,derivation of maximum likelihood estimators for parameters of standard distributions. Use of iterative procedure to derive MLE of location parameter μ of Cauchy distribution, invariance property of MLE, relation between MLE and sufficient statistic .Illustrative examples. 3.3: Method of moments: Derivation of moment estimators for standard distributions. Illustrations of situations where MLE and moment estimators are distinct and their comparison using mean square error (for uniform distribution). Illustrative examples. 3.4: Method of minimum chi-square: Definition, derivation of minimum chi-square estimator for the parameter. Illustrative examples	
UNIT - IV	**Interval Estimation**	**(12)**
	Notion of interval estimation, definition of confidence interval, length of confidence interval, confidence bounds. Definition of Pivotal quantity and its us in obtaining confidence intervals and bounds. Interval estimation for the following cases: (i) Mean μ of normal distribution (σ^2known and σ^2 unknown). (ii) Variance σ^2 of normal distribution (μ known and μ unknown). (iii) Difference between two means ($\mu1$-$\mu2$), (a) for a sample from a bivariate normal population, (b) For samples from two independent normal populations. (iv) Population proportion and difference of two population proportions of two independent large samples.	

Course Outcomes: Students should be able to

1. Understand the properties of the efficient estimator.
2. Differentiate between a point estimate and an interval estimate.
3. Compute sufficient statistics for various distributions.
4. Apply the maximum likelihood method to estimate unknown parameters,

Reference Book:

1. Kale,B. K., A first Course on Parametric Inference, S. Chand New Delhi ,2004
2. Rohatgi, V. K., Statistical Inference, Sultan Chand and Sons.,2001
3. Rohatgi, V.K. , An Introduction to Probability Theory and Mathematical Statistics, S. Chand New Delhi, 2008
4. Saxena H. C. and Surenderan Statistical Inference ,2011
5. Kendall M.G. and Stuart A., An advanced Theory of Statistics,
6. Lindgren, B. W., Statistical Theory, Macmillan Publishing Co. Inc. New York, 2000
7. Lehmann, E. L., Theory of Point Estimation, Macmillan Publishing Co. Inc. New York. 2002
8. Rao, C. R., Linear Statistical Inference, S. Chand New Delhi,2004
9. Dudewicz C.J .and Mishra S.N., Modern Mathematical Statistics

Course XI BST 503 OPERATION RESEARCH

Course Objectives: Students will be able to

1. Understand the concept of linear programming problems.
2. Solve linear programming problems by the simplex method.
3. Formulate linear programming problems.
4. Solve real-life problems using decision theory.

Credits (Total Credits 2)	SEMESTER-V BST 503 OPERATION RESEARCH	No. of hours per unit/credits
UNIT - I	**Linear Programming Problem (LPP)**	**(15)**
	1.1 : Basic concepts Statement of the Linear Programming Problem (LPP), formulation of problem as. L.P. problem. Definition of (i) a slack variable,(ii) a surplus variable. L.P. problem in(i) canonical form, (ii)standard form. Definition of(i) a solution,(ii) a feasible solution, basic variable and non-basic variable, (iv) a basic feasible solution, (v) a degenerate and a non-degenerate solution, (vi) an optimal solution. Graphical Method: Solution space, obtaining an optimal solution, unique and non-unique optimal solutions. 1.2 : Solution ofL.P.P. Simplex Method: Initial basic feasible solution (IBFS) is readily available: obtaining an IBFS, criteria for deciding whether obtained solution is optimal, criteria for unbounded solution, , more than one optimal solution. IBFS not	

	readily available: introduction of artificial variable, Big-M method, modified objective function, modifications and applications of simplex method to L.P.P., criterion for no solution. 1.3 : Duality Theory Writing dual of a primal problem, solution of L.P.P. with artificial variable. Some related theorms with proof Dual of dual is Primal (Statement and Proof), If ith constraint of primal is in standard form then ith variable of dual is unrestricted in sign or vice – versa (statement and proof) 1.4 :Examples and problems.	
UNIT - II	**Transportation and Assignment Problems**	**(12)**
	2.1Transportation problem Transportation problem(T. P.),statement of T. P., balanced and unbalanced T. P. Methods of obtaining initial basic feasible solution ofT.P. (a) North West corner rule(b)Method of matrix minima (least cost method), (c) Vogel's approximation(VAM).MODI method of obtaining Optimal solution of T. P, uniqueness s and non-uniqueness of optimal solutions, degenerate solution. Examples and problems. 2.2 Assignment Problem Statement of an assignment problem, balanced and unbalanced assignment problem, relation with T.P., optimal solution of an assignment problem using the Hungarian method. Examples and problems 2.3 : Sequencing Problem Introduction. Statement of problem. Procedure of processing n jobs on two machines. The procedure of processing jobs on three machines and machines. Computations of elapsed time and idle times. Examples and problems.	
UNIT - III	**Decision Theory**	**(8)**
	i. Introduction, steps in decision theory approach. ii. Type of decision-making environments. iii. Decision making under uncertainty: Criteria of optimism, criteria of pessimism, equally likely decision criterion, criterion of regret. iv. Decision making under risk: Expected monetary value, expected opportunity loss, the expected value of perfect information. v. Examples and problems	
UNIT - IV	**Network Analysis**	**(10)**
	4.1. Scope and definition of network model, minimal spanning tree algorithm, shortest route problem. 4.2. CPM, PERT: Network Representation, critical path computation, construction of time schedule, linear programming formulation of CPM.PERT calculations.	

Course Outcomes: Students should be able to

1. Understand the concept of assignment problems and transportation problems.
2. Optimize linear programming problems with various different methods.
3. Obtain dual of a primal problem.
4. Obtain critical path for various network problems.

Reference Book:

1. Taha H. A., Operation research – An Introduction, Fifth Edition, Prentice Hall of India, New Delhi.
2. Shrinath, L. S. , Linear Programming, Affiliated East-West Press Pvt. Ltd., New Delhi.
3. Sharma, J. K. , Mathematical Models in Operations Research, Tau McGraw Hill Publishing Company Ltd., New Delhi.
4. Kapoor, V. K. , Operations Research, Sultan Chand and Sons, New Delhi.
5. Gupta, P. K. and Hira, D. S. , Operations Research, S. Chand and Company Ltd., New Delhi.

Course XII Elective – I BST 504 DESIGNS OF EXPERIMENTS

Course Objectives: Students will be able to

1. Understand the importance of the Design of Experiments.
2. Differentiate between CRD, RBD, and LSD.
3. Calculate factor levels that optimize the outcome of an experiment
4. Demonstrate various principles of design.

Credits (Total Credits 2)	**SEMESTER-V BST 504 DESIGNS OF EXPERIMENTS**	**No. of hours per unit/credits**
UNIT - I	**Introduction and CRD**	**(10)**
	1.1: Basic Concepts: i. Basic terms in design of experiments: Experimental unit, treatment, layout of an experiment. ii. Basic principles of design of experiments: Replication, randomization and local control. iii. Choice of size and shape of a plot for uniformity trials, the empirical formula for the variance per unit area of plots. iv Concept and definition of efficiency of a design. 1.2: Completely Randomized Design (CRD) i. Application of the principles of design of experiments in CRD, layout, model, assumptions and interpretations: ii. Estimation of parameters, expected values of mean sum of squares, components of variance. iii. Breakup of total sum of squares in to components. iv. Techniqueof one way analysis of variance (ANOVA) and its applications to CRD.	

	v.Testing for equality for treatment effects and its interpretation. F-test for testing H0, test for equality of two specified treatment effects.	
UNIT - II	**RBD and LSD**	**(15)**
	2.1: Randomized Block Design(RBD): i. Application of the principles of design of experiments in RBD, layout, model , assumptions and interpretations: ii. Estimation of parameters, expected values of mean sum of squares, components of variance. iii. Breakup of total sum of squares into components. iv. Technique of two way analysis of variance (ANOVA) and its applications to RBD. v.Tests and their interpretations , test for equality of two specified treatment effects, comparison of treatment effects using critical difference (C.D.). vi. Idea of missing plot technique. vii. Situations where missing plot technique is applicable. viii. Analysis of RBD with single missing observation. ix. Efficiency of RBD over CRD. 2.2 Latin Square Design (LSD) i. Application of the principles of design of experiments in LSD, layout, model, assumptions and interpretations: ii. Breakup of total sum squares into components. iii. Estimation of parameters, expected values of mean sum of squares,components of variance. preparation of analysis of variance (ANOVA) table. iv. Tests and their interpretations, test for equality of two specified treatment effects, comparison of treatment effects using critical difference (C.D.). v. Analysis of LSD with single missing observation. vi. Identification of real life situations where CRD, RBD AND LSD are used.	

	vii.Efficiency of LSD over CRD and LSD over RBD.	
UNIT - III	**Parallel Design and ANOCOVA**	**(8)**
	3.1 Introduction to Parallel Design, its advantages and disadvantages, Cross over design its advantages and disadvantages, longitudinal design, its advantages and disadvantages, Cross sectional design its advantages and disadvantages. Comparison of Parallel Design and Cross over design . Comparison of longitudinal design and Cross Sectional design 3.2 Analysis of Covariance (ANOCOVA) with one concomitant variable i. Purpose of analysis of covariance. ii. Practical situations where analysis of covariance is applicable. iii. Model for analysis of covariance in CRD and RBD. Estimation of parameters (derivations are not expected). iv. Preparation of analysis of covariance (ANOCOVA) table, test for $\beta = 0$, test for equality of treatment effects (computational technique only). Note :- For given data, irrespective of the outcome of the test of regression coefficient (β), ANOCOVA should be carried out.	
UNIT - IV	**Factorial Experiments**	**(10)**
	i. General description of factorial experiments, 22 and 23 factorial experiments arranged in RBD. ii. Definitions of main effects and interaction effects in 22 and 23 factorial experiments. iii. Model , assumptions and its interpretation. iv. Preparation of ANOVA table by Yate's procedure, test for main effects and interaction effects. v. General idea and purpose of confounding in factorial experiments. vi. Total confounding (Confounding only one interaction) : ANOVA table, testing main effects and interaction effects. vii. Partial Confounding (Confounding only one interaction per replicate): ANOVA table, testing main effects and interaction effects.	

	viii. Construction of layout in total confounding and partial confounding in 2^3 factorial experiments.	

Course Outcomes: Students should be able to

1. Understand the basic concept of the design of the experiment.
2. Compute main and interaction effects in factorial experiments.
3. Apply CRD, RBD and LSD on real life problems.
4. Build Analysis of the covariance model on real life data.

Reference Book:

1. Federer, W.T. : Experimental Design, Oxford and IBH publishing Company, New Delhi.
2. Cochran, W.G. and Cox, G.M. : Experimental Design, John Wiley and Sons, Inc., New York.
3. Montgomery, D.C.: Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
4. Das, M.N. and Giri, N.C. : Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
5. Goulden, G.H. : Methods of Statistical Analysis, Asia Publishing House, Mumbai.
6. Kempthrone, O. : Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
7. Snedecor, G.W. and Cochran, W.G. : Statistical Methods, Affiliated East-West Press, New Delhi.
8. Goon, Gupta, Dasgupta : Fundamental of Statistics, Vol. I and II, The World Press Pvt. Ltd. Kolkata.
9. Gupta, S.C. and Kapoor, V.K. : Fundamentals of Applied Statistics, S. Chand & Sons, New Delhi.
10. C.F. Jeff Wu, Michael Hamada : Experiments, Planning Analysis and Parameter Design Optimization.

Course XII Elective – II BST 504 DEMOGRAPHY AND VITAL STATISTICS

Course Objectives: Students will be able to

1. Understand the importance of population studies.
2. Differentiate between birth rates and mortality rates.
3. Compute the mortality rate and the birth rate for different populations.
4. Construct a life expectancy table

Credits (Total Credits 2)	SEMESTER-V BST 504 DEMOGRAPHY AND VITAL STATISTICS	No. of hours per unit/credits
UNIT - I	**Population Theories**	**(10)**

	Population Theories: Coverage and content errors in demographic data, use of balancing equations and Chandrasekaran- Deming formula to check completeness of registration data. Adjustment of age data, use of Myer and UN indices, Population composition, dependency ratio.	
UNIT - II	**Sources of data on vital statistics**	**(15)**
	Introduction: Sources of data on vital statistics, errors in census and registration data. Measurement of population, Rates and ratios of vital events. Measurements of Mortality: Crude Death Rate (CDR), Specific Death Rate (SDR), Standardized Death Rate, Cause of Death Rate, Case Fatality Rate, Infant Mortality Rate (IMR), Maternal Mortality Rate (MMR), Neonatal and Perinatal Mortality Rates.	
UNIT - III	**Life (Mortality)Table**	**(10)**
	Life (Mortality) Tables: Assumption, descriptions of Complete and A bridged Life Tables, Cohort vs. Current Life Tables, Stationary and Stable population, Construction of Complete Life Table from population and death statistics, Central Mortality Rates and Force of Mortality, Uses of Life Tables. Measurements of Morbidity: Morbidity Incidence and Morbidity Prevalence Rates. Measurements of Fertility: Crude Birth Rate (CBR), General Fertility Rate (GFR), Specific Fertility Rate (SFR) and Total Fertility Rate (TFR).	
UNIT - IV	**Measurement of Population Growth**	**(10)**
	Measurement of Population Growth: Crude rates of natural increase, Pearl's Vital Index, Gross Reproduction Rate(GRR)and Net Reproduction Rate (NRR).Population Estimation, Projection and Forecasting: Use of A.P. and G.P. methods for population estimates, Use of component method for population projection, Fitting of Logistic curve for population forecasting using Rhode's method.	

Course Outcomes: Students should be able to

1. Understand the concept of Vital Statistics.

2. Measure the population growth.

3. Compute specific fertility rates for different populations.

4. Collect data of the vital events.

Reference Book:

1. Asha A. Bhende and Tara Kanitkar, Principles of Population Studies, Sixteenth Revised Edition, Himalaya Publishing House, Mumbai. 2003.
2. Jacob S. Siegel and David a. Swanson, The Methods and Materials of Demography, Second Edition, Elsevier Science, USA, 2004.
3. Hinde, Demographic Methods, Andrew London: Arnold, 1998.
4. K.B. Pathak, and F. Ram, Techniques of Demographic Analysis, Mumbai: Himalaya Publishing House, 1998.
5. 5United Nations, Methods of Measuring Internal Migration, Manual VI, UN, New York, 1974.
6. Coale, Ansley J. and Paul, Demney, Regional Model Life Tables and Stable Populations, Academic Press, New York, 1983.
7. United Nations, Model Life Tables for Developing Countries, NewYork, 1982

Course XII Elective – III BST 504 MACHINE LEARNING TECHNIQUE

Course Objectives: Students will be able to

1. Understand the importance of machine learning.

2. Differentiate between classification and regression problems.

3. Fit various machine learning algorithms on real life data.

4. Evaluate the performance of the machine learning model.

Credits (Total Credits 2)	**SEMESTER-V** **BST 504** **DEMOGRAPHY AND VITAL STATISTICS**	**No. of hours per unit/credits**
UNIT - I	**Data understanding and data cleaning**	**(11)**
	Concept of supervised and unsupervised learning. Problem of classification, classification techniques: k-nearest neighbor, decision tree, Naïve Bayesian, classification based on logistic regression, Bayesian belief Network., CART(classification and regression trees)	

UNIT - II	**Model evaluation and selection**	**(10)**
	Metrics for Evaluating Classifier Performance, Holdout Method and Random Subsampling, Cross-Validation, Bootstrap, Model Selection Using Statistical Tests of Significance, Comparing Classifiers Based on Cost–Benefit and ROC Curves.	
UNIT - III	**Techniques to Improve Classification Accuracy:**	**(12)**
	Introduction to Ensemble Methods, Bagging, Boosting and AdaBoost, Random Forests, Improving Classification Accuracy of Class-Imbalanced Data.	
UNIT - IV	**Unsupervised learning**	**(12)**
	Clustering: k-mediods, CLARA, DENCLUE, DBSCAN, Probabilistic model based clustering. Market Basket Analysis: Association rules and prediction, Apriori Algorithm, data attributes, applications to electronic commerce.	

Course Outcomes: Students should be able to

1. Understand the concept of supervised and unsupervised learning algorithms.

2. Distinguish between unsupervised and supervised ML algorithims.

3. Improve the accuracy of the classifier through Ensemble methods.

4. Perform clustering algorithms on real life data

Reference Book:

1. Berson and S. J. Smith, Data warehousing, Data Mining, and OLAP, McGraw-Hill, 1997

2. J.H. Breiman, R.A. Friedman, Olshen and C.J. Stone, Classification and Regression Trees, Wadsworth and Brooks / Cole, 1984

3. Jiawei Han, Micheline Kamber and Jian Pei, Data Mining: Concepts and Techniques, Elsevier, 3rd Edition,2012

4. T. M. Mitchell, Machine Learning, McGraw-Hill.,1997

5. B. D. Ripley, Pattern Recognition and Neural Networks , Cambridge University Press.,1996

6. V. N. Vapnik, The nature of Statistical learning theory , Springer, 2000

Course XIII SECCST – 507 Basic Numerical Skill in Computational Statistics

Course Objectives: Students will be able to

1. Understand the structure of the C programming language, data types, and library functions.
2. Apply control statements and loop control statements in programs.
3. Implement C – programs for the Statistical concepts.

Credits (Total Credits I)	**SEMESTER-V** **SECCST – 507** **Basic Numerical Skill in Computational Statistics**	**No. of hours per unit/credits**
UNIT - I	**Introduction of C Programming**	**(10)**
	Unit – 1: Introduction of C Programming 1.1 History of C, importance of C, general language structure, character set, key words, identifiers, constants, types of constants, variables, data type (character, integer, floating point, long int, double, exponential), declaration of variables, assignment statement, assigning values to variables. 1.2 Operators and expressions: Arithmetic operators, relational operators, relational expression, logical operators, increment operator, decrement operator, arithmetic expressions, library functions: cos(x), sin(x), tan(x), exp(x), abs(x), floor(x), mod(x, y), log(x), log10(x), pow(x, y), sqrt(x), random( ), randomize( ). 1.3 Input and output operators: getchar(), putchar(), scanf(), printf(),Conversion specification-%c %d, %f, %s, %e, %u. Escape sequences: \n, \t 1.4 Strings String of characters input/output functions for using gets( ), puts( ). Use of standard string library function sstrlen, strwr, strupr, strrev, strchr, strcmp, strcpy and strcat. Programs using string	
UNIT - II	**Decision Making and Arrays**	**(22)**
	2.1.Decision Control statement: if, if... else statement, switch statement, simple illustrative examples. 2.2 Loop control statements: Concept and use of looping, while, do. while, for, compound assignment operators, break, continue, exit, goto, nested loops, programs using control statements. 2.3 Arrays Concept of arrays, one-dimensional array, declaration of one-dimensional array, initialization of one-dimensional array. Two-dimensional array, declaration of two- dimensional array, initialization of two-dimensional array. Programs using arrays	

Course Outcomes: Students should be able to

1. Understand string data types and arrays.
2. Differentiate between one dimensional and two-dimensional array
3. Construct c programming using arrays.

Reference Book:

1. Yashavant P. Kanetkar, Let Us C, BPB Publications, 13th Edition, 2014
2. E. Balgurusamy, Programming in ANSI C, Tata McGraw Hill Education Private Limited, 5th edition, 2013
3. Greg Perry, C Programming Absolute Beginner's Guide, Que Publishing, 3rd edition, 2015
4. Kernighan Brian W., C Programming Language, Pearson 2nd edition, 2015

Practical Paper V BSP 508 Probability Distribution – I and Statistical Inference - I

Course Objectives: Students will be able to

1. Understand the concept of fitting of distribution and model sampling.
2. Simulate data from various univariate continuous distribution.
3. Apply minimum chi-square method to estimate parameter
4. Construct confidence interval for parameters of the distribution.

Credits (Total Credits 4)	SEMESTER-V **BSP 508** Probability Distribution – I and Statistical Inference - I	No. of hours per unit/credits
	List of Practical Probability Distribution – I	
	1. Model sampling from Laplace and Cauchy distributions 2. Model sampling from Pareto distribution. 3. Model sampling from truncated binomial and poison distributions. 4. Model sampling from truncated normal and exponential distributions. 5. Fitting of Weibull distribution. 6. Fitting of truncated Binomial distribution. 7. Fitting of truncated Poisson distribution. 8. Decomposition of mixture type c.d.f. into discrete and continuous c.d.f.'s. 9. Applications of Weibull, Laplace and Pareto distribution.	
	List of Practical Statistical Inference – I	
	1. Point estimation by method of moments for discrete distributions. 2. Point estimation by method of moment for continuous distributions. 3. Point estimation by method of maximum likelihood (one parameter). 4. Point estimation by method of maximum likelihood (two parameters).	

	5. Point estimation by method of minimum chi-square. 6. Interval estimation of location and scale parameters of normal distribution (single sample). 7. Interval estimation of difference of location and ratio of scale parameters of normal distribution (two samples). 8. Interval estimation for population proportion and difference between two population proportions.	

Course Outcomes: Students should be able to

1. Understand different methods of the parameter estimation.
2. Estimate unknown parameters by the method of moments.
3. Fit univariate continuous distribution on given real life data
4. Apply Weibull distribution to solve real life problems.

Reference Book:

1. Cramer H. , Mathematical Methods of Statistics, Asia Publishing House, Mumbai, 2005
2. Mood, A. M., Gray bill K, Bose. D. C , Introduction to Theory of Statistic, Mc-Graw Hiil Series, 2005.
3. Lindgren B.W, Statistical Theory (Third Edition), Collier Macmillan International Edition, Macmillan Publishing Co. Inc. New York, 2004.
4. Hogg, R. V. and Craig A. T., Introduction to Mathematical Statistics (Third Edition), Macmillan Publishing Company, 2000.
5. Sanjay Arora and Bansi Lal, New Mathematical Statistics (First Edition), Satya Prakashan, New Market, New Delhi, 1989.
6. Gupta S. C and Kapoor V. K., Sultan Chand and Sons, Fundamentals of Mathematical Statistics,
7. Rohatgi V. K., An Introduction to Probability Theory and Mathematical Statistics, Wiley
8. Kale,B. K., A first Course on Parametric Inference, S. Chand New Delhi ,2004
9. Saxena H. C. and Surenderan Statistical Inference ,2011
10. Kendall M.G. and Stuart A., An advanced Theory of Statistics,
11. Lindgren, B. W., Statistical Theory, Macmillan Publishing Co. Inc. New York, 2000
12. Lehmann, E. L., Theory of Point Estimation, Macmillan Publishing Co. Inc. New York. 2002
13. Rao, C. R., Linear Statistical Inference, S. Chand New Delhi,2004

Practical Paper VI BSP 509 Operations Research and Design of Experiments

Course Objectives: Students will be able to

1. Understand the concept of CRD and RBD
2. Estimate missing observation using missing plot techniques
3. Solve linear programming problem using simplex method
4. Obtain minimal path for network problems

Credits (Total Credits 4)	SEMESTER-V **BSP 509** **Operations Research and Design of Experiments**	No. of hours per unit/credits
	List of Practical Operations Research	
	1. L.P.P. by simplex method I (Slack variable) 2. L.P.P. by simplex method II (Big M method) 3. Transformation problem-I. 4. Transformation problem-II. (Degeneracy) 5. Assignment problem. 6. Sequencing Problem. 7. Decision Theory. 8.Construction of CPM and PERT. 9. Minimal Path and cut.	
	List of Practical Statistical Inference – I	
	1. Analysis of CRD and RBD. 2. Analysis of Latin Square Design (LSD). 3. Missing Plot Technique for RBD and LSD with one missing observation. 4. Efficiency of i) RBD over CRD and ii) LSD over CRD and RBD. 5.Analysis of Split plot and strip plot Design. 6. Analysis of Covariance in CRD 7. Analysis of Covariance in RBD 8. Analysis of 2^2 and 2^3 Factorial Experiment 9. Total and partial Confounding	

Course Outcomes: Students should be able to

1. Solve Assignment and Sequencing problem.
2. Construct CPM and PERT for network problem.
3. Analyse design of experiment through split plot and strip plot design.
4. Preform analysis of CRD and RBD design.

Reference Book:

1. Taha H. A., Operation research – An Introduction, Fifth Edition, Prentice Hall of India, New Delhi.
2. Shrinath, L. S. , Linear Programming, Affiliated East-West Press Pvt. Ltd., New Delhi.

3. Sharma, J. K. , Mathematical Models in Operations Research, Tau McGraw Hill Publishing Company Ltd., New Delhi.
4. Kapoor, V. K. , Operations Research, Sultan Chand and Sons, New Delhi.
5. Gupta, P. K. and Hira, D. S. , Operations Research, S. Chand and Company Ltd., New Delhi.
6. Federer, W.T. : Experimental Design, Oxford and IBH publishing Company, New Delhi.
7. Cochran, W.G. and Cox, G.M. : Experimental Design, John Wiley and Sons, Inc., New York.
8. Montgomery, D.C.: Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
9. Das, M.N. and Giri, N.C. : Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
10. Goulden, G.H. : Methods of Statistical Analysis, Asia Publishing House, Mumbai.
11. Kempthrone, O. : Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
12. Snedecor, G.W. and Cochran, W.G. : Statistical Methods, Affiliated East-West Press, New Delhi.
13. Goon, Gupta, Dasgupta : Fundamental of Statistics, Vol. I and II, The World Press Pvt. Ltd. Kolkata.
14. Gupta, S.C. and Kapoor, V.K. : Fundamentals of Applied Statistics, S. Chand & Sons, New Delhi.
15. C.F. Jeff Wu, Michael Hamada : Experiments, Planning Analysis and Parameter Design Optimization.

Practical Paper VII BSP 510 Basic Numerical Skills in Computational Statistics

Course Objectives: Students will be able to

1. Understand the different data types in the C programming
2. Write C code to solve simple statistical problem

Credits (Total Credits 1)	SEMESTER-V **BSP 510** Basic Numerical Skills in Computational Statistics	No. of hours per unit/credits
	List of Practical	
	1. Data types and in built functions 2. Control Statements: if, if...else and switch statement 3. Loop control statement - I: while and do … while statement 4. Loop control statement - II: for statement 5. One dimensional and two-dimensional array	

Course Outcomes: Students should be able to

1. Use loop control statement in C programs.

2. Differentiate between the one dimensional and two dimensional array

Reference Book:

1. Yashavant P. Kanetkar, Let Us C, BPB Publications, Thirteenth Edition, 2014
2. E. Balgurusamy, Programming in ANSI C, Tata McGraw Hill Education Private Limited, Fifth edition, 2013
3. Greg Perry, C Programming Absolute Beginner's Guide, Que Publishing, 3rd edition, 2015
4. Kernighan Brian W., C Programming Language, Pearson 2nd edition, 2015

Course XIV BST 601 PROBABILITY DISTRIBUTION - II

Course Objectives: Students will be able to

1. Various application of probability in real life.
2. Basic of Stochastic Process, Markov chain, Queuing theory with some proof and their real life examples.
3. Mathematical proof of Central limit theorem and weak law of large number.

Credits (Total Credits 2)	**SEMESTER-VI** **BST 601** **PROBABILITY DISTRIBUTION - I**	**No. of hours per unit/credits**
UNIT - I	**Convergence and Central Limit Theorem**	**(10)**
	1.1**: Convergence** i. Definition of convergence of sequence of random variables(a) in distribution,(b) in probability, Almost sure convergence (c) in rth mean. ii. If $X_n \xrightarrow{p} X$ then $g(X_n) \xrightarrow{p} g(X)$ where g is continuous function without proof. iii. Examples and problems. **1.2: Weak Law of Large Numbers and Central Limit Theorem** i. Weak law of large numbers (WLLN) statement and proof for i. i. d. random variables with finite variance. ii. Central limit theorem: Statement and proof for i. i. d. random variables with finite variance, proof based on m.g.f.. iii. Simple examples based on Bernoulli, binomial, Poisson and chi- square distribution.	
UNIT - II	**Markov Chain**	**(10)**
	2.1 Definition of Stochastic process, state space ,parameter space, types of stochasticprocesses ,first order Markov property, Markov chains (MC), finite MC, timehomogeneous M.C. one step transition probabilities, and transition probability matrix (t.p.m.),stochastic matrix, Chapman Kolmogorov	

	equation, n step transition probabilitymatrix , n-step tpm of two state M.C. and some typical t. p. m .initial distribution, finite dimensional distribution functions , partial sum(and functions of independent and identically distributed random variables as Markov chain, illustrations such as random walk, Gambler'srun problem, Ehren fest chain) **2.2** Communicating states, first return probability, probability of ever return Classificationof states , as persistent and transient states , irreducible MC.	
UNIT - III	**Stochastic Process**	**(10)**
	3.1 Definition of stochastic process. **3.2** Postulates and difference differential equations for : i) Pure birth process ii) Poisson process with initially 'a' members, for a =0 and a>0 iii) Yule Furry process iv) Pure death process v) Death process with $\mu n = \mu$ vi) Death process with $\mu n = n\mu$ vii) Birth and death process	
UNIT - IV	**Non-central $\chi 2$ Distribution**	**(12)**
	Non-central $\chi 2$ Distribution with Non-centrality Parameter , moment generating function, Additive or reproductive Property, Cumulants of Non-central $\chi 2$ Distribution.	

Course Outcomes: Students should be able to

1. Solve Convergence and Central Limit Theorem.
2. Understand Markov Chain and its applications.
3. Understand Stochastic Processes and its applications.
4. Know the application and nature of non-central distribution

Reference Book:

1. Mathematical Methods of Statistics, Cramer H.: Asia Publishing House, Mumbai. 2005
2. Statistical Theory (Third Edition), Lindgren B. W.: Collier Macmillan International Edition, Macmillan Publishing Co.Inc. New York. 1997
3. Introduction to Mathematical Statistics (Third Edition), Hogg, R. V. and Craig A. T. : MacmillanPublishingCompany,Inc.866,34dAvenue,NewYork, 2009.

4. New Mathematical Statistics (First Edition), Sanjay Arora and Bansi Lal : Satya Prakashan,16/17698, New Market, New Delhi, 5 (1989).
5. Fundamentals of Mathematical Statistics, Gupta S. C and Kapoor V. K. : Sultan Chandand Sons, 88, Daryaganj, New Delhi 2000
6. An Introduction to Probability Theory and Mathematical Statistics, Rohatgi V. K.: Wiley
7. Stochastic Processes. Medhi J : Wiley Eastern Ltd. New Delhi. 2009
8. Introduction to Stochastic Processes, Houghton Mifflin. 2005
9. An Introduction of Probability Theory and its Applications. Feller. W. : Wiley Eastern 2002
10. Modern Probability Theory. Bhat B. R.: Sultan Chandand Sons, 88, Daryaganj, New Delhi 1997
11. Stochastic Models : Bhat B. R.: Analysis and Applications. New Age International. 2003

Course XV BST 602 STATISTICAL INFERENCE - II

Course Objectives: Students will be able to

1. Understand the concept of testing of hypothesis
2. Apply parametric and non-parametric tests in real-life situation.
3. Perform the Likelihood Ratio Test to test the hypothesis regarding the parameter.
4. Construct Sequential analysis by Wald SPRT.

Credits (Total Credits 2)	**SEMESTER-VI** **BST 602** **STATISTICAL INFERENCE - II**	**No. of hours per unit/credits**
UNIT - I	**Parametric Tests**	**(12)**
	1.1 Statistical hypothesis, problems of testing of hypothesis, definitions and illustrations of (i) simple hypothesis (ii) composite hypothesis, critical region, type I and type II error, probabilities of type I & type II errors. Power of a test, p-value, size of a test, level of significance, problem of controlling probabilities of type I & type II errors. 1.2 Definition of Most Powerful (MP) test. Statement and proof (sufficient part) of Neyman Pearson (NP) lemma for simple null hypothesis against simple alternative hypothesis for construction of MP test. Examples of construction of MP test of level $\propto$	

	1.3 .Power function of a test, power curve, definition of uniformly most powerful (UMP) level $\propto$ test. Use of NP lemma for constructing UMP level α test for one-sided alternative. Illustrative examples.	
UNIT - II	**Likelihood Ratio Test**	**(10)**
	2.1 Notion of likelihood ratio test (LRT), $\Lambda(x) = \text{Sup } L(\theta_0\|x) / \text{Sup } L(\theta\|x)$ 2.2 Construction of LRT for H0: $\theta = \theta_0$ against H1: $\theta \neq \theta_0$ for the mean of normal distribution for i) Known $\sigma 2$ ii) unknown $\sigma 2$ (one sided and two sided alternatives). 2.3 LRT for variance of normal distribution for i) known μ ii) unknown μ (one sided and two sided alternatives hypotheses). 2.4 LRT for parameters of binomial and exponential distribution for two sided alternatives only. 2.5 LRT as a function of sufficient statistics, statement of asymptotic distribution of LRT statistic	
UNIT - III	**Sequential Tests**	**(10)**
	3.1 General theory of sequential analysis and its comparison with fixed sample procedure. Wald's SPRT of strength$(\propto,\beta)$,for simple null hypothesis against simple alternative hypothesis. 3.2 Illustrations for standard distributions like binomial, Poisson, exponential and normal. Graphical and tabular procedure for carrying out the test. Illustrative examples.	
UNIT - IV	**Non- parametric Test**	**(13)**
	4.1 Notion of non-parametric statistical inference (test) and its comparison with parametric Statistical inference. Concept of distribution free statistic. 4.2 Test procedure of: (i) Run test for one sample (i.e. test for randomness) and run test for two independent sample problems. (ii) Sign test for one sample and two sample paired observations (iii) Wilcoxon's signed rank test for one sample and two sample paired observations. (iv) Mann-Whitney U -test (two independent samples) (v) Median test (vi) Empirical distribution function Sn(x). Properties of Sn(x) as estimator of F(.) Kolmogorov Smirnov test for one and for two independent samples. Comparison with chi-square test.	

Course Outcomes: Students should be able to

1. Understand the concept of testing of hypothesis.

2. Differentiate between parametric and non-parametric test

3. Construct the most powerful Critical region (MP) and uniform most powerful critical region (UMP)

4. Compute Type I, Type II error and power of test

Reference Book:

1. S.C.Gupata and V.K.Kapoor, Fundamental of mathematical statistics,2002

2. Daniel, Applied Non parametric statistics, Wiley Easten Ltd

3. Rohatgi, V. K., Statistical Inference,Wiley Eastern Ltd. New Delhi.,2000

4. Rohatgi, V.K., An introduction to Probability Theory and Mathematical Statistics, Wiley, 1996

5. Saxena H.C. and Surenderan , Statistical Inference, Wiley Eastern Ltd. New Delhi. 2010

6. Cassela G. And Berger R.L., Statistical Inference, Wiley Eastern Ltd. New Delhi.2010

7. Lehmann, E. L, Testing of Statistical Hypothesis,1999

8. Gibbons, J. D, Non-parametric Statistical Inference.

Course XVI BST 603 INDUSTRIAL STATISTICS

Course Objectives: Students will be able to

1. Understand the concept of process control and product control.
2. Construct control charts such as the CUMSUM chart and moving average chart.
3. Apply the Six Sigma methodology to improve the process.
4. Differentiate between process control and lot control.

Credits (Total Credits 2)	SEMESTER-VI BST 603 INDUSTRIAL STATISTICS	No. of hours per unit/credits
UNIT - I	**Quality Tools**	**(10)**
	Meaning and dimensions of quality, quality philosophy, Magnificent tools of quality: Histogram, Check sheet, Pareto diagram, cause and effect diagram, scatter diagram, control chart, flow chart. Deming's PDCA cycle for continuous improvements and its applications.	
UNIT - II	**Process Control**	**(12)**

	CUSUM chart, tabular form, use of these charts for monitoring process mean. Moving average and exponentially weighted moving average charts. Introduction to six-sigma methodology, DMAIC cycle and case studies. Introduction ARL and its use in SPC. Introduction to Process Capability and its use in SPC.	
UNIT - III	**Product Control**	**(13)**
	Sampling Inspection plans for attribute inspection: Concept of AQL, LTPD, Consumer's risk, producer's risk, AOQ, AOQL, OC, ASN and ATI. Description of Single and double sampling plans with determination of above constants. Multiple sampling plans, Sequential sampling plan, The Dodge-Roaming sampling plan.	
UNIT - IV	**Lean and Six Sigma**	**(10)**
	Overview of Lean and Six Sigma with principles. Methodologies – Introduction to SCORE, DMAIC, Six Sigma Roles and Responsibilities. Tools used in Define Phase. Tools used in Measure Phase. Spaghetti diagram. Tools used in Analyze Phase. Various Statistical Techniques used in analyze Phase (Revision), Tools used in Improve/Design Phase. Tools used in Control/Verify Phase.	

Course Outcomes: Students should be able to

Reference Book:

1. Introduction to Quality Control – Montgomery D. C.
2. Quality Control and Industrial Statistics Duncan A J
3. Statistical Quality Control by E L Grant
4. Data Mining-Concept and Techniques, Jiawei Han. Micheline Kamber and Jian Pei.
5. Data Mining- Introductory and Advanced Topics, Margret. H and Dunham
6. Introduction to Data Mining with case studies, G.K.Gupta
7. Data Mining Application with R: Zhao.

Course XVII Elective I BST 604 SAMPLING THEORY

Course Objectives: Students will be able to

1. Understand the basic terminology of sampling techniques.
2. Differentiate between systematic and cluster sampling.
3. Implement various sampling methods while conducting the survey.
4. Determine sample size for sample survey.

Credits (Total Credits 2)	SEMESTER-VI BST 604 SAMPLING THEORY	No. of hours per unit/credits
UNIT - I	**Basic Terminology and Simple Random Sampling**	**(15)**
	1.1 Basic Terminology Concept of distinguishable elementary units, sampling units, sampling frame, random sampling and non-random sampling. Concept of Probability and Non-Probability Sampling. Methods of Non-Probability Sampling. Advantages of sampling method over census method, objectives of a sample survey, Designing a questionnaire, Characteristics of a good questionnaire, Concept of sampling and non-sampling errors. Handling of non-response cases. 1.2: Simple random sampling i. Simple random sampling from finite population of size N with replacement (SRSWR) and without replacement (SRSWOR): Definitions, population mean and population total as parameters, inclusion probabilities. ii. Sample mean $\bar{y}_n$as an estimator of population mean, derivation of its expectation, standard error and estimation of standard error. iii. N$\bar{y}_n$ as an estimator of population total, derivation of its expectation, standard error and estimator of standard error. iv. Sampling for dichotomous attributes. Estimation of population proportion Sample proportion(p)as an estimator of population proportion(P), derivation of its expectation, standard error and estimator of standard error using SRSWOR. Np as an estimator of total number of units in the population possessing the attribute of interest, derivation of	

	its expectation, standard error and estimator of standard error 1.3 Determination of the samples size. Determination of the sample size (n) for the given: i. Margin of error and confidence coefficient. ii. Coefficient of variation of the estimate and confidence coefficient.	
UNIT - II	**Stratified Sampling**	**(15)**
	i.Real life situations where stratification can be used. ii. Description of stratified sampling method where sample is drawn from individual stratum using SRSWOR method. iii. (a) $\bar{y}_{st}$ as an estimator of population mean $\bar{Y}$, derivation of its expectation, standard error and estimator of standard error. (b) st Ny as an estimator of population total, derivation of its expectation, standard error and estimator of standard error. iv. Problem of allocation: Proportional allocation, Neyman's allocation and optimum allocation, derivation of the expressions for the standard errors of the above estimators when these allocations are used. v. Comparison amongst SRSWOR, stratification with proportional allocation and stratification with optimum allocation. vi. Cost and variance analysis in stratified random sampling, minimization of variance for fixed cost, minimization of cost for fixed variance, optimum allocation as a particular case of optimization in cost and variance analysis.	
UNIT - III	**Other Sampling Methods**	**(10)**

	3.1: Systematic Sampling i. Real life situations where systematic sampling is appropriate. Technique of drawing a sample using systematic sampling. ii. Estimation of population mean and population total, standard error of these estimators. iii. Comparison of systematic sampling with SRSWOR. iv. Comparison of systematic sampling with SRSWOR and stratified sampling in the presence of linear trend. v. Idea of Circular Systematic Sampling 3.2: Cluster Sampling i. Real life situations where cluster sampling is appropriate. Technique of drawing a sample sing cluster sampling. ii. Estimation of population mean and population total (with equal size clusters), standard error of these estimators iii. Systematic sampling as a particular case of cluster sampling. 3.3 Two Stage and Multi Stage Sampling Idea of two-stage and multistage sampling.	
UNIT - IV	**Sampling Methods using Auxiliary variables**	**(5)**
	4.1: Ratio Method i. Concept of auxiliary variable and its use in estimation ii. Situations where Ratio method is appropriate. iii. Ratio estimators of the population mean and population total and their standard errors(without derivations),estimators of the standard errors. iv. Relative efficiency of ratio estimators with that of SRSWOR 4.2: Regression Method i. Situations where Regression method is appropriate. ii. Regression estimators of the population mean and population total and their standard errors (without derivations), estimators of these standard errors. iii. Comments regarding bias in estimation iv. Relative efficiency of regression estimators with that of a) SRSWOR b) Ratio estimator	

Course Outcomes: Students should be able to

1. Understand basic terminology used in sampling procedure and Simple Random Sampling.
2. Apply simple random sampling in real life situation.
3. Differentiate between systematic and stratified sampling.
4. Conduct survey to collect primary data.

Reference Book:

1. Cochran,W.G, Sampling Techniques, Wiley Eastern Ltd., NewDelhi.2012

2. Sukhatme,P.V. and Sukhatme B.V. , Sampling Theory of Surveys with Applications, Indian Society of Agricultural Statistics, New Delhi.1989

3. Des Raj, Sampling Theory, S. Chand 2017

4. Daroga Singh and Choudhary F.S., Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd., New Delhi.

5. Murthy, M.N, Sampling Methods,Indian Statistical Institute, Kolkata. 1998

6. Mukhopadhay, Parimal, Theory and Methods of Survey Sampling,: Prentice Hall. 2003

Course XVII Elective II BST 604 SURVEY SAMPLING and OFFICIAL STATISTICS

Course Objectives: Students will be able to

1. Understand the concept of population and sample
2. Differentiate between complete enumeration and sampling.
3. Perform sampling through various different methods
4. Estimate population parameter from the samples.

Credits (Total Credits 2)	SEMESTER-VI **BST 604** SURVEY SAMPLING and OFFICIAL STATISTICS	No. of hours per unit/credits
UNIT - I		**(15)**
	Concept of population and sample, complete enumeration verses sampling, sampling and non-sampling error, Types of sampling: Non-Probability and Probability sampling, basic principle of sample survey, Simple Random Sampling With and Without Replacement, definition and procedure of selecting a sample, estimates of: population mean, total and proportion, variances of these estimates, estimates of their variances and sample size determination.	
UNIT - II		**(15)**
	Stratified Random Sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocation and their comparison with SRS. Practical difficulties in allocation, estimation of gain in precision, post stratification and its performance. Systematic Sampling: Technique, estimates of population mean and total variances of these estimates (N=n k). Comparison of systematic sampling with SRS and Stratified Sampling in the presence of linear trend and corrections	
UNIT - III		**(10)**
	Introduction to Ratio and Regression method of estimation, first approximation to the population mean and total(for SRS of large size), MSE of these estimates and estimates of these variances, MSE in term of correlation coefficient for regression method of estimation and their comparison with SRS. Cluster sampling (Equal clusters only) estimation of population mean and variance, comparison(with and without randomly formed clusters). Concept of sub sampling, Two-stage sampling. Estimation of Population mean and variance of the estimate	
UNIT - IV		**(5)**
	An outline of present official statistical system in India, Methods of collection of official statistics, their reliability and limitation. Role of Ministry of Statistics and Problem Implementation (MoSPI), Central Statistical Office (CSO), National Sample Survey Office (NSSO), Registered	

	General Office and National Statistical Commission, Government of India's Principal publications containing data on topics such as Agriculture, price, population, industry, finance and employment Consumer price index, Wholesale price Index number and Index of industrial production National Income: Basic idea and a brief description of income, expenditure and production approaches	

Course Outcomes: Students should be able to

1. Understand the need of official statistics.

2. Conduct small sample survey.

3. Apply various sampling techniques in real life situations.

4. Compute consumer price index, wholesale price index and index of industrial production.

Reference Book:

1. Cochran,W.G, Sampling Techniques, Wiley Eastern Ltd., NewDelhi.2012

2. Sukhatme,P.V. and Sukhatme B.V. , Sampling Theory of Surveys with Applications, Indian Society of Agricultural Statistics, New Delhi.1989

3. Des Raj, Sampling Theory., S. Chand 2017

4. Daroga Singh and Choudhary F.S., Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd., New Delhi.

5. Murthy, M.N, Sampling Methods,Indian Statistical Institute, Kolkata. 1998

6. Mukhopadhay, Parimal, Theory and Methods of Survey Sampling,: Prentice Hall. 2003

7. M. R. Saluja, Indian Official Statistical System, Statistical Pub, Society, 1972

8. Walter J. Radermacher, Official Statistics 4.0, Springer, 2020

Course XVII Elective III, BST 604 RELIABILITY THEORY

Course Objectives: Students will be able to

1. Understand the concept of the reliability theory
2. Compute survival rate, hazard rate and failure rate function.
3. Categorize life distributions into IFR class or DFR class.
4. Measure the reliability of various components and system

Credits (Total Credits 2)	SEMESTER-VI BST 604 RELIABILITY THEORY	No. of hours per unit/credits
UNIT - I		(12)

	Structure function, dual of a structure, cuts and paths, components & systems, coherent systems, redundancy, Pivotal decomposition, Associated random variables and their properties. Birnbaum's measure of structural importance. Reliability concepts and measures, reliability of coherent systems, bounds on system reliability, Modular decomposition.	
UNIT - II		**(10)**
	Life time distributions, survival functions, failure rate function, cumulative hazard function, residual life time, survival function of residual life time, mean residual life time, Computation of these functions for Common life time distributions: exponential, Weibull, Gamma, Makeham, Pareto, Rayleigh.	
UNIT - III		**(13)**
	Notion of ageing: IFR, DFR, IFRA, DFRA, DMRL, NBU, NWU, NBUE, NWUE classes, ageing properties of common life time distributions, closure properties under formation of coherent structures, convolutions and mixtures of these classes. Damage model, cumulative damage model, univariate shock models and life distributions arising from shock models, bivariate exponential distribution.	
UNIT - IV		**(10)**
	Stochastic ordering: usual stochastic ordering, hazarad rate ordering, reverse hazard rate ordering, dispersive ordering, mean residual life ordering and their implications. Availability, interval reliability, availability of a system with a single spare and a repair facility	

Course Outcomes: Students should be able to

1. Understand the concept of life time distribution.
2. Calculate reliability of parallel and series system.
3. Use different life time distribution under complete sampling.
4. Identify whether system is coherent or not.

Reference Book:

1. Barlow R. E and Proschen F , Statistical Theory of Reliablity and Life Testing, Holt Rinchart and Winstone, 1985

2. Rausand M and Hoyland A, System Reliability theory – Models, Statistical Methods and its application, Wiley, 2004

3. Sinha S. K , Reliability and life testing, Wiley, 1986

4. Nelson W. B, Applied Life Data Analysis, Wiley, 2003

5. Lawless J. F, Statistical models and Methods of Life Tima Data. Wiley, 1982

Course XVIII SECCST 607 Entrepreneurship Development Program

Course Objectives: Students will be able to

1. Understand the product design and development process

2. Identify opportunities for entrepreneurship

3. Prepare project report for small scale business

4. Develop small scale business.

Credits (Total Credits 1)	SEMESTER-VI SECCST 607 Entrepreneurship Development Program	No. of hours per unit/credits
Unit - I	**Product Design and Development**	**(06)**
	Introduction, Product development basics, Product development stages, Identification of customer requirements, Designing the product, Techno commercial feasibility of a product, Pilot production batch, Product assessment, Failure rates of electronic components, Touch screen, Multi-touch technology.	
Unit - II	**Entrepreneurship Development**	**(06)**
	Introduction to entrepreneurship, Identification of opportunities for entrepreneurship, Concept of different occupations: - business, employment and profession. Functions of an entrepreneur. Business idea and plan, Types of businesses/ownerships – Sole Proprietorship, Partnership, Private limited company, Public limited company, Joint-stock Company, Co-operative society.	
Unit - III	**Sources of Finance**	**(05)**
	Preparation of project report for business, Sources of finance – government and non-government agencies, Working capital, Cash flow, Fund flow, Preparation of basics of financial statements, costing and pricing, Policies and incentives.	
Unit - IV	**Marketing Management**	**(05)**
	Small business management and entrepreneurship, Woman entrepreneurship, Features of small business firms, Process of management in small business, Concept of data and information, Information as a commodity, Study of marketing strategy and	

	marketing mix, Decision-making models, Types of decisions, Decision Support Systems, Introduction to e-commerce, types – B2B, B2C, C2B, C2C.	

Course Outcomes: Students should be able to

1. Identify feasibility of product design and development
2. Get the idea about IP rights
3. Avail the financial and marketing skill
4. Prepare the proposal for small scale industry.

Reference Book :

1.R. G. Kaduskar, V. B. Baru. Electronic Product Design. Second edition Wiley India

2. Alpana Trehan. Entrepreneurship. Wiley India

3. G. N. Pandey. A complete guide to successful Entrepreneurship, Vika

Practical Paper VIII BSP 608 Probability Distribution and R – Software

Course Objectives: Students will be able to

1. Understand the use of R – software for statistical analysis
2. Simulate data from various distributions using R – software
3. Implement various sampling methods while conducting the survey.
4. Determine sample size for sample survey.

Credits (Total Credits 4)	SEMESTER-VI **BSP 608** Probability Distributions and R – Software and Statistical Inference - II	No. of hours per unit/credits
	List of Practical Probability Distributions and R – Software	
	1. Model sampling from Log-normal and Weibull distributions using R-Software. 2. Model sampling from Logistic distribution using R-Software. 3. Fitting of Binomial and Poisson distributions using R-Software. 4. Fitting of Normal distribution using R-Software. 5. Fitting of Log-normal distribution using R-Software. 6. Analysis of Completely Randomized Design (CRD) using R. 7. Analysis of Randomized Block Design (RBD) using R. 8. Classification of TPM, States and computation of higher transition probabilities.	

	9. Applications of Queueing Systems.	
	List of Practical Statistical Inference – II	
	1. Construction of MP test. 2. Construction of UMP test. 3. Construction of SPRT for binomial, Poisson distributions, graphical representation of procedure. 4. Construction of SPRT for exponential and normal distribution, graphical representation of procedure. 5. NP test- -Run test (for one and two independent samples). 6. NP test –Sign test and Wilcoxon's signed rank test (for one and two samples paired observation). 7 NP test-- Mann-whitney U- test (for two independent samples). 8. NP test –Median test (for two large independent samples) 9. NP test—Kolmogorov - Smirnov test (for one and two independent samples).	

Course Outcomes: Students should be able to

1.Understand the concept of parametric and non – parametric test.

2. Construct the SPRT test for discrete as well as continuous distribution

3. Fit distribution to the real life data using R – software

4. Apply queuing theory in real life applications

Reference Book:

1. S.C.Gupata and V.K.Kapoor, Fundamental of mathematical statistics,2002

2. Daniel, Applied Non parametric statistics, Wiley Easten Ltd

3. Rohatgi, V. K., Statistical Inference,Wiley Eastern Ltd. New Delhi.,2000

4. Rohatgi, V.K., An introduction to Probability Theory and Mathematical Statistics, Wiley, 1996

5. Saxena H.C. and Surenderan , Statistical Inference, Wiley Eastern Ltd. New Delhi. 2010

6. Cassela G. And Berger R.L., Statistical Inference, Wiley Eastern Ltd. New Delhi.2010

7. Lehmann, E. L, Testing of Statistical Hypothesis,1999

8. Gibbons, J. D, Non-parametric Statistical Inference.

9. John Verzani, Using R for Introductory Statistics, Chapman & Hall, 2014

10. Tilman M. Davies, A First Course in Programming and Statistics, No Starch Press, 2016

Practical Paper IX BSP 609 Industrial Statistics & Sampling Methods

Course Objectives: Students will be able to

1. Understand the concept of process control and product control.
2. Construct control charts such as the CUMSUM chart and moving average chart.
3. Implement various sampling methods while conducting the survey.
4. Determine sample size for sample survey.

Credits (Total Credits 4)	SEMESTER-VI **BSP 609** Industrial Statistics & Sampling Methods	No. of hours per unit/credits
	List of Practical Industrial Statistics	
	1.EWMA-Chart. 2. CUSUM chart. 3. Six sigma limits for mean. 4. Single sampling plan-I (Small sample). 5. Single sampling plan-II (Large sample). 6. Double sampling plan-I (Small sample. 7. Double sampling plan-II (Large sample). 8. k-nearest neighbor technique for classification. 9.k-means technique for clustering	
	List of Practical Sampling Methods	
	1. Simple Random Sampling for Variables. 2. Simple Random Sampling for Attributes. 3. Determination of Sample Size in SRS for Variables and Attributes. 4. Stratified Random Sampling – I 5. Stratified Random Sampling – II 6. Ratio Method of Estimation. 7. Regression Method of Estimation. 8. Systematic Sampling. 9. Cluster Sampling	

Course Outcomes: Students should be able to

1. Understand basic terminology used in sampling procedure and Simple Random Sampling.
2. Apply simple random sampling in real-life applications.

3. Apply the Six Sigma methodology to improve the process.

4. Differentiate between process control and lot control.

Reference Book:

1. Introduction to Quality Control – Montgomery D. C.

2. Quality Control and Industrial Statistics Duncan A J

3. Statistical Quality Control by E L Grant

4. Cochran,W.G, Sampling Techniques, Wiley Eastern Ltd., NewDelhi.2012

6. Sukhatme,P.V. and Sukhatme B.V. , Sampling Theory of Surveys with Applications, Indian Society of Agricultural Statistics, New Delhi.1989

7. Des Raj, Sampling Theory, S. Chand 2017

8. Daroga Singh and Choudhary F.S., Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd., New Delhi.

Practical Paper X SECCSP 610

Industrial Project Course Work

Industrial Visits and report writing,Preparation of entrepreneurship Proposal and Presentation