Academic Council Meeting No. and Date: 3 / February 14, 2022

Agenda Number: 2 **Resolution Number: 4.9 & 4.18**

Vidya Prasarak Mandal's
B. N. Bandodkar College of
Science (Autonomous), Thane

Syllabus for

Programme: Bachelor of Science

Specific Programme : STATISTICS

[S.Y.B.Sc. (Statistics)]

Revised under Autonomy

From academic year 2022-23

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Preamble

The B.Sc. Statistics programme is aimed to develop theoretical and analytical skills of the students so that they may be absorbed in the corporate world or able to pursue higher studies at the Master level in Statistics. The main objectives of the course are:

- To get introduced to some statistical concepts that are relevant in the interpretation of measurements made on individual, and in the interpretation of statistical study materials.
- To apply their knowledge and skills to be employed and excel in Statistics professional careers and/or to continue their education in Statistics and/or related post graduate programmes.
- To get Knowledge and understanding of basic statistical methods such as sampling and collecting data, probability, distributions, Regression Analysis.
- To gain Knowledge and understanding to confidently read statistics and apply statistical methods within their working environment.
- To be capable of managing Statistics projects with consideration of the human, financial and environmental factors.
- To work effectively as a part of a team to achieve a common stated goal.
- To communicate effectively with a range of audiences both technical and non-technical.
- To develop an aptitude to engage in continuing professional development.

The syllabus is aimed to achieve the objectives. The syllabus spanning three years covers the industry relevant courses. The students will be ready for the jobs available in different fields like:

- Statistician
- Analyst
- Biostatistician
- Actuaries
- Banking sector
- Risk Analyst
- Machine Learning and Artificial Intelligence
- Data Analytics
- Academics
- Government organizations like NSSO, NSO, ISS, SSC etc.

The students will also be trained in communication skills and knowledge related to R software.

Eligibility:

Cleared F.Y.B.Sc with a Combination PMS/EMS from any recognized/ Affiliated University can adopt for S.Y.B.Sc with the subject combination of MS/PS.

Duration: 2 years

Mode of Conduct:

Statistics Practical's / Practical's are related to R software / Offline lectures / online lectures.

Program Specific Outcome

By the end of the programme, Learner Enhance knowledge of Statistical tools, Able to relate real life situation with statistical technique, Enable efficient use of electronic devices to solve statistical problems, Develop the ability to use statistical knowledge and skills in other disciplines.

VPM's B. N. Bandodkar College of Science (Autonomous), Thane

S.Y.B.Sc. (Statistics)

Structure of Programme

Course Code	Course Title	No. of lectures	Credits
BNBUSST3T1	PROBABILITY DISTRIBUTIONS	**45**	**2**
BNBUSST3T2	THEORY OF SAMPLING	**45**	**2**
BNBUSST3T3(A)	OPERATION RESEARCH 1	**45**	**2**
BNBUSST3T3(B)	STATISTICAL PROGRAMMING WITH PYTHON - I	**45**	**2**
BNBUSST3P1	Practical's based on BNBUSST3T1 Practical's based on BNBUSST3T2 Practical's based on BNBUSST3T3	**45**	**3**
Total		**180**	**09**

Course Code	Course Title	No. of lectures	Credits
BNBUSST4T1	PROBABILITY AND SAMPLING DISTRIBUTIONS	**45**	**2**
BNBUSST4T2	ANALYSIS OF VARIANCE & DESIGN OF EXPERIMENTS	**45**	**2**
BNBUSST4T3(A)	OPERATION RESEARCH 2	**45**	**2**
BNBUSST4T3(B)	STATISTICAL PROGRAMMING WITH PYTHON - II	**45**	**2**
BNBUSST4P1	Practical's based on BNBUSST4T1 Practical's based on BNBUSST4T2 Practical's based on BNBUSST4T3	**45**	**3**
Total		**180**	**09**

Semester III

Course Code	Course Title	Credits	No. of lectures
BNBUSST3T1	PROBABILITY DISTRIBUTIONS	2	

Course Outcomes: Upon completion of this course, students will acquire knowledge about and able to

- Understand Univariate and Bivariate Random variable.
- Understand different Standard Discrete Probability Distributions.
- Solve problem after identifying the underlying distribution.
- Get Knowledge about different generating function.

Unit I : — **15**

Univariate Random Variables (Discrete and Continuous):

- **Moment Generating Function(M.G.F.):**Definition, Properties.
- **Cumulant Generating Function(C.G.F.):** Definition, Properties. Obtaining Cumulants using C.G.F. Relationship between moments and cumulants upto order four.
- **Characteristic Function-** Definition and properties (without Proof) Examples of obtaining raw moments and central moments up to order four using M.G.F. and C.G.F. for continuous and
- **Discrete Distributions.**

1. **Discrete Uniform Distribution:-**Mean, Variance, coefficient of skewness using M.G.F.
2. **Bernoulli distribution:-**Mean, Variance, coefficient of skewness using M.G.F.
3. **Degenerate Distribution (One point distribution) P(X=c) =1**, Mean, Variance, Use of Degenerate distribution.
4. **Binomial Distribution:-**Mean, Variance, Measures of skewness and Kurtosis based on moments using M.G.F.and C.G.F. , Nature of probability curve, Mode, Additive property , If X follows Binomial, then to find distribution of n-X.

- Recurrence relation for moments with proof:

$$\mu'_{r+1} = np\,\mu'_r + pq\frac{d}{dp}\mu'r$$

$$\mu_{r+1} = pq\,[\,nr\,\mu_r + \frac{d}{dp}\mu r]$$

- Relation between Bernoulli and Binomial using M.G.F.
- Transformation of random Variable (Univariate) : examples based on it.

Unit II : — **15**

Standard Discrete Probability Distributions:

- **Poisson Distribution:-** Mean, Variance, Measures of skewness and Kurtosis based on moments using M.G.F.and C.G.F. , Nature of probability curve, Mode, Additive property. Recurrence relation for moments with proof for μ'_{r+1}, μ_{r+1}. If X and Y are two independent Poisson variables Conditional distribution of X given X+Y with proof
- Poisson distribution as limiting distribution of Binomial (with proof) Real life examples of Binomial, Poisson distribution.
- **Geometric Distribution:-** Definition in terms of No. of failures and No. of trials.Mean, Variance, M.G.F., Mean and Variance using M.G.F., C.G.F., Mean and Variance,μ_3, μ_4 using C.G.F., Coefficients of skewness and Kurtosis and nature of probability curve. Lack of Memory property with proof. If X and Y are two i.i.d. Geometric variables; Conditional distribution of X given X+Y with proof.

	Distribution of k i.i.d. Geometric variables • **Negative Binomial Distribution Definition**: - Mean, Variance, M.G.F., Mean and Variance using M.G.F., C.G.F., Mean, Variance,μ_3,μ_4 using C.G.F., Coefficients of skewness and Kurtosis and nature of probability curve. Lack of Memory property with proof.Recurrence relation for probabilities, Fitting of distribution • Limiting distribution of Negative Binomial distributionwith proof • **Hyper Geometric Distribution**: -Definition,Mean,Variance,Limiting distribution of Hyper geometric distribution • If X and Y are two independent Binomial variables Conditional distribution of X given X+Y • **Definition of Truncated distribution:**-Truncated Binomial and Truncated Poisson Distribution:truncated at 0 Suitable illustrations, probability mass function, mean and variance. Real life situations of Geometric, Negative Binomial, Hypergeometric distributions	
Unit III :	**Bivariate Probability Distributions:** • **Two Dimensional Discrete Random Variables :-** Joint Probability mass function and its properties,Distribution function and its properties,Definition of raw and central moments, covariance, correlation coefficient, Independence and correlation between two variables,Marginal and conditional probability distributions,Conditional expectation, conditional variance. • **Continuous bivariate random variables :-** Joint Probability density function and its properties,Distribution function and its properties,Definition of raw and central moments, covariance, correlation coefficient, Independence and correlation between two variables,Marginal and conditional probability distributions,Conditional expectation, conditional variance,Regression Function. Transformation of Random Variables and Jacobian of transformation with illustrations.	**15**

REFERENCES:

1. Introduction to the theory of statistics: A. M. Mood, F.A. Graybill, D. C. Boyes, Third Edition; McGraw-Hill Book Company.
2. Introduction to Mathematical Statistics: R.V.Hogg, A.T. Craig; Fourth Edition; Collier McMillan Publishers.
3. Probability and Statistical Inference: R.V.Hogg, E. A.Tannis, Third Edition; Collier McMillan Publishers.
4. John E. Freund's Mathematical Statistics: I. Miller, M. Miller; Sixth Edition; Pearson Education Inc.
5. Introduction to Mathematical Statistics: P.G. Hoel; Fourth Edition; John Wiley & Sons Inc.
6. Fundamentals of Mathematical Statistics: S.C. Gupta, V.K. Kapoor; Eighth Edition; Sultan Chand & Sons.
7. Mathematical Statistics: J.N. Kapur, H.C. Saxena; Fifteenth Edition; S. Chand & Company Ltd.
8. Statistical Methods: An Introductory Text: J. Medhi; Second edition; Wiley Eastern Ltd.
9. An Outline of Statistical Theory Vol. 1: A.M. Goon, M.K. Gupta, B. DasGupta; Third Edition; The World Press Pvt. Ltd.

Course Code BNBUSST3T2	Course Title THEORY OF SAMPLING	Credits 2	No. of lectures

Course Outcomes: Upon completion of this course, students will acquire knowledge about and able to

- Understand different concepts of sampling.
- Understand different sampling technique.
- How use this technique for real life data.
- Comparison of sampling technique.

Unit I :	**Concepts of Sampling and Simple Random SamplingProbability:** • Population, Population unit, Sample, Sample unit, Parameter, Statistic, Estimator, Bias, Unbiasedness, Mean square error & Standard error.Census survey, Sample Survey. Steps in conducting a sample survey with examples on designing appropriate Questionnaire. Concepts of Sampling and Non-sampling errors. NSSO, CSO and their functions.Concepts and methods of Probability and Non-Probability Sampling. • **Simple Random Sampling:** (SRS).Definition, Sampling with & without replacement (WR/WOR).Lottery method & use of Random numbers to select Simple random sample Estimation of population mean & total. Expectation & Variance of the estimators, Unbiased estimator of variance of these estimators. (WR/WOR).Estimation of population proportion. Expectation & Variance of theestimators, unbiased estimator of variance of these estimators. (WR/WOR). Estimation of Sample size based on a desired accuracy in case of SRS for variables & attributes. (WR/WOR).	**15**
Unit II :	**Stratified Sampling :** • **Stratified Sampling:** Need for Stratification of population with suitable examples.Definition of Stratified Sample. Advantages of stratified Sampling. • **Stratified Random Sampling:** Estimation of population mean & total in case of Stratified Random Sampling (WOR within each strata). Expectation & Variance of the unbiased estimators, unbiased estimators of variances of these estimators.Proportional allocation, Optimum allocation with and without varying costs. Comparison of Simple Random Sampling, Stratified Random Sampling using Proportional allocation & Neyman allocation.	**15**
Unit III :	**Ratio and Regression Estimation:** • **Ratio & Regression Estimation assuming SRSWOR:** Ratio Estimators for population Ratio, Mean & Total. Expectation & MSE of the Estimators. Estimators of MSE. Uses of Ratio Estimator. Regression Estimators for population Mean & Total. Expectation & Variance of the Estimators assuming known value of regression coefficient 'b'. Estimation of 'b'. Resulting variance of the estimators. Uses of regression Estimator. Comparison of Ratio, Regression & mean per Unit estimators. • Introduction to Systematic sampling, Cluster sampling & Two Stage sampling with suitable illustrations.	**15**

REFERENCES:

1. Sampling Techniques: W.G. Cochran; 3rd Edition; Wiley(1978)
2. Sampling Theory and methods: M.N. Murthy; Statistical Publishing Society. (1967)
3. Sampling Theory: Des Raj; McGraw Hill Series in Probability and Statistics. (1968).
4. Sampling Theory of Surveys with Applications: P.V. Sukhatme and B.V. Sukhatme; 3rd Edition; Iowa State University Press (1984).
5. Fundamentals of Applied Statistics: S. C. Gupta and V.K. Kapoor; 3rd Edition; Sultan Chand and Sons (2001).
6. Theory and Analysis of Sample Survey Designs: Daroga Singh, F.S.Chaudhary, Wiley Eastern Ltd. (1986).
7. Sampling Theory and Methods: S. Sampath, Second Edition (2005),Narosa.
8. Theory and Methods of Survey Sampling: Parimal Mukhopadhyay, (1998), Prentice Hall of India Pvt. Ltd.

Course Code BNBUSST3T3(A)	Course Title OPERATIONS RESEARCH 1	Credits 2	No. of lectures

Course Outcomes: Upon completion of this course, students will acquire knowledge about and able to

- Solve and formulated mathematical models of real life situation.
- Apply operation research techniques in industries.
- Understand how to optimize transportation problem using different technique.
- Solve assignment problem with optimum cost and time.

Unit I :	**Linear Programming Problem (L.P.P.) :** • Mathematical Formulation: Maximization & Minimization. Concepts of Solution, Feasible Solution, Basic Feasible Solution, Optimal solution. Graphical Solution for problems with two variables. Simplex method of solving problems with two or more variables. Big M method. Concept of Duality. Its use in solving L.P.P. Relationship between optimum solutions to Primal and Dual. Economic interpretation of Dual.	**15**
Unit II :	**Transportation Problem:** • Concept, Mathematical Formulation.Concepts of Solution, Feasible Solution. Initial Basic Feasible Solution by North-West CornerRule,MatrixMinima Method, Vogel's Approximation Method. Optimal Solution by MODI Method. Optimality test, Improvement procedure. • Variants in Transportation Problem: Unbalanced, Maximization type.	**15**
Unit III :	**Assignment Problem:** • Concept. Mathematical Formulation Solution by: Complete Enumeration Method and Hungarian method. Variants in Assignment Problem: Unbalanced, Maximization type. Travelling Salesman Problem. • **Sequencing :** Processing n Jobs through 2 and 3 Machines & 2 Jobs through m Machines.	**15**

REFERENCES

1. Operations Research: Kantiswaroop and Manmohan Gupta. 4th Edition; S Chand & Sons.
2. Schaum Series book in O.R. Richard Broson. 2nd edition Tata Mcgraw Hill Publishing Company Ltd.
3. Operations Research: Methods and Problems: Maurice Sasieni, Arthur Yaspan and Lawrence Friedman,(1959), John Wiley & Sons.
4. Mathematical Models in Operations Research : J K Sharma, (1989), Tata McGraw Hill Publishing Company Ltd.
5. Principles of Operations Research with Applications to Management Decisions: Harvey M. Wagner, 2nd Edition, Prentice Hall of India Ltd.
6. Operations Research: S.D.Sharma.11th edition, Kedar Nath Ram Nath & Company.
7. Operations Research: H. A.Taha.6th edition, Prentice Hall of India.
8. Quantitative Techniques For Managerial Decisions: J.K.Sharma , (2001), MacMillan India Ltd.

Course Code BNBUSST3T3(B)	Course Title STATISTICAL PROGRAMMING WITH PYTHON- I	Credits 2	No. of lectures

Course Outcomes: Upon completion of this course, students will acquire knowledge about and able to

- They will able to understand python programming.
- They will able to code real life situations in python programming.
- To understand basic functions and syntax of python.

Unit I :	**Introduction to Python Programming :** • Programming Languages, its features, Introduction to IDLE Interpreter, its basic syntax, built-in Number types, Expression, Operators, Built-in function Type, Operator Precedence. • Detail of Statements: Expression, Assert, Assignment, Augmented, del, Import. • Python Input/Output with print() and input() function, Function, Defining and Calling function, Function Call. • Compound Data Type: Strings, Updating Strings, Tuples, Accessing Values in Tuples, Updating Tuples, Delete Tuple elements, Lists, Accessing Values in Lists, Updating Lists, Delete List elements. • Built-in function: Min, Max, and Sum.	**15**
Unit II :	**Functions & Control Statements:** • Function: Advantage, Types, Return Statement, Passing Values by Reference and by Value, Function Arguments, Recursive Function, Scope of Variable, Range function. • Conditional Statement: If, If-else, if-then-else, Nested If. • Looping: For loop, For loop with else, While loop, Nested loop. • Control Statement: Break, Continue, Pass Statement. • Dictionary: Dictionaries, Accessing values in Dictionary, Updating Dictionary, Delete elements from Dictionary.	**15**
Unit III:	**List Comprehensions & OOP in Python:** • Anonymous Function, List Comprehensions, Directory Methods in Python. • Introduction to object oriented Programming. • Methods: Methods of Strings, Methods of Tuples, Methods of Lists, Methods of Dictionaries.	**15**

REFERENCES

1. Programming with Python – I : Sachin A. Thanekar, Manisha S. Abhyankar, Rasika Mundhe.
2. Python for Data Analysis by O'Reilly Media (2nd Edition).
3. Python for Data Analysis by Armando Fernandgo.

Course Code BNBUSST3P1	Course Title PROBABILITY DISTRIBUTIONS & THEORY OF SAMPLING & OPERATION RESEARCH 1 & PROGRAMMING WITH PYTHON – I Practical's	Credits 3	No. of lectures
Practical No.	**PROBABILITY DISTRIBUTIONS Practical's**		
1	Moment Generating Function, Moments.		**3**
2	Cumulant generating Function, Cumulants, Characteristic function.		**3**
3	Standard Discrete Distributions.		**3**
4	Fitting Standard Discrete Distributions.		**3**
5	(i) Bivariate Probability Distributions, Marginal & Conditional distributions, Conditional Mean, Conditional Variance, Correlation.		**3**
6	Transformation of discrete & continuous random variables.		
	THEORY OF SAMPLING Practical's		
7	Designing of Questionnaire.		**3**
8	Simple Random Sampling for Variables.		**3**
9	Simple Random Sampling for Attributes.		**3**
10	Estimation of Sample Size in Simple Random Sampling.		**3**
11	Stratified Random Sampling.		**3**
12	Ratio Estimation.		**3**
13	Regression Estimation.		**3**
	OPERATIONS RESEARCH 1 Practical's		
14	Formulation and Graphical Solution of L.P.P.		**3**
15	Simplex Method		**3**
16	Duality		**3**
17	Transportation Problems		**3**
18	Assignment Problems		**3**
19	Sequencing Problems		**3**
	STATISTICAL PROGRAMMING WITH PYTHON – I Practical's		
1	Practical based on Unit I (A)		**3**
2	Practical based on Unit I (B)		**3**

3	Practical based on Unit II (A)	**3**
4	Practical based on Unit II (B)	**3**
5	Practical based on Unit III (A)	**3**
6	Practical based on Unit III (B)	**3**

Semester IV

Course Code BNBUSST4T1	Course Title PROBABILITY AND SAMPLING DISTRIBUTIONS	Credits 2	No. of lectures

On completion of the course, student will be able to–

- Understand different continuous distribution.
- Understand the relationship between various distributions.
- Understand the patterns in the data of large population.
- Know the properties of different continuous distributions.

Unit I :	**Standard Continuous Probability Distributions:** • **Rectangular or Continuous Uniform** over (a, b) Mean, Median Standard deviation,C.D.F., M.G.F., Mean,variance,μ_3 using M.G.F., skewness of distribution. For X following U (0,1), distribution of i) $\frac{X}{1+X}$, ii) $\frac{X}{1-X}$ • **Triangular distribution over(a, b) with peak at c:-** M.G.F. • **Exponential Distribution:-**Definition, M.G.F., C.G.F. Raw moments and central moments upto order four usingM.G.F. and C.G.F. Measures of Skewness and Kurtosis,Nature of Probability curve,Median and Quartiles,Forgetfulness Property with proof and examples based on it. Distribution of i) $X_{(1)}$,first order statistic ii) ratio of two i.i.d. Exponential variables. iii)$\frac{1}{\lambda}$ ln(1-X) if X follows Exponential with parameter λ. iv) X+Y and$\frac{X}{X+Y}$,for two independent Exponential variables X and Y with mean 1.(All with proof.) • **Cauchy (with Single & Double parameter):-**Properties without proof • **Gamma (with Single & Double parameter):-**Expression for r th raw moment,Mean, Mode & Standard deviation. M.G.F., Additive property, C.G.F. Raw moments and central moments up to order four using M.G.F. and C.G.F. Distribution of sum of independent Exponential variables. • **Beta Distribution: Type I & Type II: -** Expression for r th raw moment, Mean, Standard deviation. If a R.V. X follows Beta of type 1, distribution of 1- X If a R.V. X follows Beta of type 2, distribution of i) $\frac{1}{1+X}$, ii)$\frac{X}{1+X}$With proof.For two independent Gamma variables X and Y with parameters m and n respectively, distribution of U = $\frac{X}{Y}$ and V= $\frac{X}{X+Y}$ with proof.	**15**

Unit II :	**Normal Distribution :** • Definition, Derivation of Mean, Median, Mode, Standard deviation, M.G.F. , C,G,F., Moments & Cumulants (up to fourth order). skewness &kurtosis, Nature of Normal curve,Mean absolute deviation. Properties of Normal Distribution.Expression for even order central moments and to show that odd order central moments zero. • Distribution of Standard normal variable • Distribution of linear function of independent Normal variables (i) aX, (ii) X+b, (iii)aX+bYin particular X+Y and X-Y, (iv) aX+bY+c. (all with proof.) • Fitting of Normal Distribution. • Central Limit theorem for i.i.d. random variables.(only statement) • Log Normal Distribution: Derivation of mean & variance.	**15**
Unit III :	**Exact Sampling Distributions :** • **Chi-Square Distribution: Derivation of p.d.f.,**Concept of degrees of freedom. Mean, Mode & Standard deviation. M.G.F.,C.G.F., Measures of skewness and Kurtosis, Additive property,Distribution of ratio two independent Chi-square variables,Distribution of $\frac{X}{X+Y}$ if X and Y two independent Chi-square variables all with proof,Distribution of the sum of squares of independent Standard Normal variables. Sampling distributions of sample mean and sample variance and their independence for a sample drawn from Normal distribution (without proof). • **Applications of Chi-Square:** Development of decision criterion with test procedures of (i)Test of significance for specified value of variance of a Normal population (ii)Test for goodness of fit, • Derivation of Confidence interval for the variance of a Normal population when (i) Mean is known, , (ii) Mean is unknown. • **Student t-distribution:** Derivation ofp.d.f**.,** Mean, Median, Mode,Mean Deviation & Standard deviation. M.G.F., C.G.F., Measures of skewness and Kurtosis and Additive property,Limiting distribution of t distribution with proof. • **Applications of t:** Development of decision criterion with test procedure of Test of significance for specified value of mean of Normal population. • Test procedure of test of significance for difference between means of (i) Two independent Normal populations with equal variances (ii) Dependent samples (Paired t test)Derivation ofConfidence intervals for Mean of Normal population, difference between means of two	**15**

	independent Normal populations having the same variance. • **Snedecor's F-distribution:** Derivation of p.d.f.**,**Mean, Mode &Standard deviation Distribution of Reciprocal of F variable with proof. • Applications of F: Test procedure for testing equality of variances of two independent Normal populations (i) Mean is known (ii) Mean is unknown • Derivation of confidence interval for ratio of variances of two independent Normal populations.	

REFERENCES:

1. A M Mood, F.A. Graybill, D C Boyes; Third Edition; McGraw-Hill Book Company.: Introduction to the theory of statistics

2. R.V.Hogg, A.T. Craig; Fourth Edition; Collier McMillan Publishers.: Introduction to Mathematical Statistics

3. R.V.Hogg, E. A.Tannis, Third Edition; Collier McMillan Publishers.: Probability and Statistical Inference

4. I. Miller, M. Miller; Sixth Edition; Pearson Education Inc.: John E. Freund's Mathematical Statistics

5. P.G. Hoel; Fourth Edition; John Wiley & Sons Inc.: Introduction to Mathematical Statistics

6. S.C. Gupta, V.K. Kapoor; Eighth Edition; Sultan Chand & Sons.: Fundamentals of Mathematical Statistics

7. J.N. Kapur, H.C. Saxena; Fifteenth Edition; S. Chand & Company Ltd.: Mathematical Statistics

8. J. Medhi; Second edition; Wiley Eastern Ltd.: Statistical Methods- An Introductory Text

9. A.M. Goon, M.K. Gupta, B. DasGupta; Third Edition; The World Press Pvt. Ltd.: An Outline of Statistical Theory Vol. 1

Course Code BNBUSST4T2	Course Title ANALYSIS OF VARIANCE & DESIGN OF EXPERIMENTS	Credits 2	No. of lectures

At the end of the course, a student will be able to:

- Understand why variation occur in the data and how to analyze these variations.
- Study the different designs of experiment.
- Identify which design is suitable for given data.
- Understand factorial design and analysis of data using factorial experiment.

Unit I :	**Analysis of Variance:** • Introduction, Uses, Cochran's Theorem (Statement only). One way classification with equal & unequal observations per class, Two way classification with one observation per cell. Mathematical Model, Assumptions, Expectation of various sums of squares F- test, Analysis of variance table. • Least square estimators of the parameters, Variance of the estimators, Estimation of treatment contrasts, Standard Error and Confidence limits for elementary treatment contrasts.	**15**
Unit II :	**Design Of Experiments:** • Concepts of Experiments, Experimental unit, Treatment, Yield, Block, Replicate, Experimental Error, Precision. Principles of Design of Experiments: Replication, Randomization & Local Control. Efficiency of design D1 with respect to design D2.Choice of size, shape of plots & blocks in agricultural &nonagricultural experiments. • **Completely Randomized Design (CRD) & Randomized Block Design (RBD):** Mathematical Model, Assumptions, Expectation of various sums of squares, F-test, Analysis of variance table. Least square estimators of the parameters, Variance of the estimators, Estimation of treatment contrasts, Standard error and Confidence limits for elementary treatment contrasts. Efficiency of RBD relative to a CRD.	**15**
Unit III :	**Latin Square Design and Factorial Experiments :** • **Latin Square Design (LSD):**Mathematical Model, Assumptions, Expectation of various sums of squares, F-test, Analysis of variance table. Least square estimators of the parameters, Variance of the estimators, Estimation of treatment contrasts, Standard error and Confidence limits for elementary treatment contrasts. Efficiency of the design relative to RBD, CRD. Missing plot technique for one missing observation in case of CRD, RBD & LSD.	**15**

	• **Factorial Experiments:** Definition, Purpose & Advantages. 2^2, 2^3 Experiments. Calculation of Main & interaction Effects. Definition of contrast and orthogonal contrast, Yates' method. Analysis of 2^2 & 2^3 factorial Experiments.	

REFERENCES:

1. W.G. Cochran and G.M.Cox; Second Edition;John Wiley and Sons.: Experimental Designs

2. Oscar Kempthorne, John Wiley and Sons.: The Design and Analysis of Experiments

3. Douglas C Montgomery; 6th Edition;John Wiley & Sons.: Design and Analysis of Experiments

4. M.N.Das and N.C.Giri, 2nd Edition; New Age International (P) Limited; 1986: Design and Analysis of Experiments

5. Walter T Federer; Oxford & IBH Publishing Co. Pvt. Ltd.: Experimental Design, Theory and Application

6. S.C.Gupta and V.K.Kapoor; 3rd Edition; Sultan Chand and Sons (2001): Fundamentals of Applied Statistics

7. B.J. Winer, McGraw Hill Book Company.: Statistical Principles in Experimental Design

Course Code BNBUSST4T3(A)	Course Title OPERATIONS RESEARCH 2	Credits 2	No. of lectures

Course Outcomes: Upon completion of this course, students will acquire knowledge about and able to

- To solve real problems using operation research technique.
- To plan and schedule projects using network analysis.
- To understand the concept of Quality, Causes, Risk, Control charts, 3σ limits and 6σ limits.

Unit I :	**CPM and PERT :** Objective and Outline of the techniques. Diagrammatic representation of activities in a project: Gantt Chart and Network Diagram. Slack time and Float times. Determination of Critical path. Probability consideration in project scheduling. Project cost analysis. Updating.	**15**
Unit II :	**Game Theory :** Definitions of Two persons Zero Sum Game, saddle point, Value of the Game, Pure and mixed strategy, optimal solution of two person zero sum games. Dominance property, Derivation of Formulae for (2 x 2) game. Graphical solution of (2 x n) and (m x 2) games, Reduction of game theory to LPP.	**15**
Unit II :	**Statistical Quality Control :** • Introduction, Assignable causes, Chance causes, Process control, Product control, Shewhart's control charts, 3σ limits. • $\bar{X}$ and R, p, c, np charts, their uses, p-chart with variable sample size. • Problems involving setting up standards for future use. Process ca Expected probability.	**15**
Unit III :	**Decision Theory:** • Decision making under uncertainty: Laplace criterion, Maximax (Minimin) criterion, Maximin(Minimax) criterion, Hurwitz α criterion, Minimax Regret criterion. • Decision making under risk: Expected Monetary Value criterion, Expected Opportunity Loss criterion, EPPI, EVPI. • Bayesian Decision rule for Posterior analysis. • Decision tree analysis along with Posterior probabilities.	**15**
Unit III :	**Acceptance Sampling :** • Introduction to Lot Acceptance Sampling Plans by Attributes, Consumers Risk, Producers Risk, Single and Double Sampling Plans : OC function and OC curves, AQL, LTPD, ASN, ATI, AOQ, Concept of 6σ limits.	**15**

REFERENCES:

1. Duncan D.B. , 3rd edition, Taraporwala sons & co .: Quality Controland Industrial Statistics

2.2nd edition, McGraw-Hill Publishers:Statistical Quality Control

3. Sirnath, 2nd edition, East West Press Pvt Ltd..: PERT and CPM Principles and Applications

4. Kantiswaroop, P.K. Gupta and Manmohan, 4th edition, Sultan Chand & Sons. ; 1986: Operation Research

5. S.D.Sharma, 11th edition, Kedaarnath, Ramnath and Co.: Operation Research

6.H.A.Taha 6th edition, Prentice Hall of India : Operation Research

7. V.K.Kapoor, 7th edition, Sultan Chand & Sons. : Operation Research

Course Code BNBUSST4T3(B)	Course Title STATISTICAL PROGRAMMING WITH PYTHON-II	Credits 2	No. of lectures

At the end of the course, a student will be able to:

- They will able to plot using matplot library.
- They will know how to read excel file in python.
- They can able to test the statistical analysis using python.

Unit I :	**Numpy, Pandas and Data Exploration:** • Numpy arrays: Creating arrays crating n-dimensional arrays using np.array and array operations (indexing and slicing, transpose, mathematical operations). • Pandas dataframes: Creating series and dataframes and Operations on series and dataframes. • Reading and writing data: From and to Excel and CSV files. • Text data operations: len, upper, lower, slice, replace, contains. • Frequency Tables	**15**
Unit II :	**Descriptive Statistics and Statistical Methods:** • Plotting: using "matplotlib" (Histograms, Box plots, Scatter plot, Bar plot, Line plot) • Descriptive Statistics: mean, median, mode, min, max, quantile, std, var, skew, kurt, correlation. • Probability Distributions: (using scipy.stats) • Simulation from distributions, computations of probabilities, Cumulative probabilities, quantiles and drawing random sample using functions for following distributions: Binomial, Poisson, Hypergeometric, normal, exponential, gamma, Cauchy, Lognormal, Weibull, uniform, Laplace, Graphs of pmf/pdf by varying parameters for above distributions and fitting of distributions.	**15**
Unit III :	**Inferential Statistics:** • Hypothesis testing and t test: (using scipy.stats, math) ttest_1samp, ttest_ind(2 sample test), ttest_rel(paired), Type I and Type II error • Chi-Square tests: (using scipy.stats) chisquare, chhi2 • ANOVA: (using scipy.stats) f_oneway • Linear regression: from sklearn import linear model and use linearmodel.linearregression function.	**15**

REFERENCES

1. Python for Data Analysis by O'Reilly Media (2nd Edition).
2. Python for Data Analysis by Armando Fernandgo.
3. How to think like a computer scientist learning with Python by Allen Downey.

Course Code BNBUSST4P1	Course Title PROBABILITY AND SAMPLING DISTRIBUTIONS ANALYSIS OF VARIANCE & DESIGN OF EXPERIMENTS & OPERATION RESEARCH 2 PROGRAMMING WITH PYTHON – II Practical	Credits 3	No. of lectures
Practical No.	**PROBABILITY AND SAMPLING DISTRIBUTIONSPractical's**		
1	Standard Continuous distributions.		**3**
2	Normal Distribution.		**3**
3	Central Limit Theorem.		**3**
4	Chi Square distribution.		**3**
5	t distribution.		**3**
6	F distribution.		**3**
	ANALYSIS OF VARIANCE & DESIGN OF EXPERIMENTSPractical's		
8	Analysis of Variance- One Way.		**3**
9	Analysis of Variance- Two Way.		**3**
10	Completely Randomized Design.		**3**
11	Randomized Block Design.		**3**
12	Latin Square Design.		**3**
13	Missing Observations in CRD, RBD & LSD.		**3**
14	Factorial Experiments.		**3**
	OPERATIONS RESEARCH 2 Practical's		
15	PERT		**3**
16	CPM		**3**
17	Project cost analysis		**3**
18	Updating		**3**
19	Control Charts for attributes		**3**
20	Control Charts for variables		**3**
21	Acceptance Sampling Plans.		**3**
	STATISTICAL PROGRAMMING WITH PYTHON – II Practical's		
22	Descriptive Statistics		**3**
23	Correlations and Simple Regression		**3**
24	Probability Distributions : Discrete		**3**
25	Probability Distributions : Continuous		**3**
26	Statistical Test: t test, F test and Chisquare		**3**
27	ANOVA		**3**

Evaluation Scheme

Internals

Internal Test	Any Certificate Course of at least 30hrs from nptel / swayam /udemy based on excel / SQL / Power BI / python / tableau any software OR Case Study/ Mini Research Project OR R/SPSS Certificate Course provided by the Department	Total
20	20	40

Internal Examination:

Based on Unit 1 / Unit 2 / Unit3

Duration: 1Hour **Total Marks:20**

	Answer the following	20
Q. 1		
Q. 2		
Q. 3		
Q. 4		

Theory Examination

Suggested Format of Question paper

Duration:2 Hour **Total Marks:60**

- **All questions are compulsory**

Q. 1	Answer ***any two*** of the following		**16**
	a	Based on Unit I	
	b	Based on Unit I	
	c	Based on Unit I	
Q. 2	Answer ***any two*** of the following		**16**
	a	Based on Unit II	
	b	Based on Unit II	
	c	Based on Unit II	
Q. 3	Answer ***any two*** of the following		**16**
	a	Based on Unit III	
	b	Based on Unit III	
	c	Based on Unit III	
Q. 4	Answer the following		
	a	State True or False :	**4**
	(i)	Based on Unit I/Unit II/ Unit III	
	(ii)	Based on Unit I/Unit II/ Unit III	

	(iii)	Based on Unit I/Unit II/ Unit III	
	(iv)	Based on Unit I/Unit II/ Unit III	
	b	Answer in one sentence:	**8**
	(i)	Based on Unit I/Unit II/ Unit III	
	(ii)	Based on Unit I/Unit II/ Unit III	
	(iii)	Based on Unit I/Unit II/ Unit III	
	(iv)	Based on Unit I/Unit II/ Unit III	

Marks Distribution and Passing Criterion for Each Semester

Theory					**Practical**		
Course Code	Internal	Min marks for passing	Theory Examination	Min marks for passing	Course Code	Practical Examination	Min marks for passing
BNBUSST3T1	**40**	**16**	**60**	**24**	BNBUSST3P1	**150**	**60**
BNBUSST3T2	**40**	**16**	**60**	**24**			
BNBUSST3T3	**40**	**16**	**60**	**24**			

Theory					**Practical**		
Course Code	Internal	Min marks for passing	Theory Examination	Min marks for passing	Course Code	Practical Examination	Min marks for passing
BNBUSST4T1	**40**	**16**	**60**	**24**	BNBUSST4P1	**150**	**60**
BNBUSST4T2	**40**	**16**	**60**	**24**			
BNBUSST4T3	**40**	**16**	**60**	**24**			

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