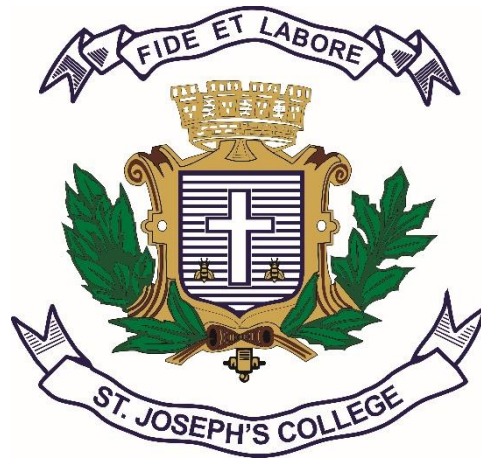


ST. JOSEPH'S COLLEGE (AUTONOMOUS)

BENGALURU-27



Re-accredited with 'A++' GRADE with 3.79/4 CGPA by NAAC
Recognized by UGC as College of Excellence

DEPARTMENT OF STATISTICS

Syllabus for Bachelor of Science (Basic/Hons.)

**With Statistics as one of the majors with practical with other subject as another
major in 3rd year
Under National Education Policy**

For Batch 2021

Name of the Degree Program: B.Sc.

Discipline Core: Statistics

Total Credits for the Program: 176 (till 8 semesters)

Starting year of implementation: 2021-22

Program Outcomes

By the end of the program the students will be able to:

1. Acquire fundamental/systematic or coherent understanding of the academic field of Statistics and its different learning areas and applications.
2. Develop and demonstrate an ability to understand major concepts in various disciplines of Statistics.
3. Demonstrate the ability to use skills in Statistics and different practicing areas for formulating and tackling Statistics related problems and identifying and applying appropriate principles and methodologies to solve a wide range of problems associated with Statistics.
4. Understand procedural knowledge that creates different types of professionals related to subject area of Statistics, including professionals engaged in government/public service and private sectors.
5. Plan and execute Statistical experiments or investigations, analyze and interpret data/information collected using appropriate methods, including the use of appropriate statistical software including programming languages, and report accurately the findings of the experiment/investigations.
6. Have a knowledge regarding use of data analytics tools like Excel and R-programming.
7. Developed ability to critically assess a standard report having graphics, probability statements.
8. Analyze, interpret the data and hence help policy makers to take a proper decision.
9. Recognize the importance of statistical modelling and computing, and the role of approximation and mathematical approaches to analyze the real problems using various statistical tools.
10. Demonstrate relevant generic skills and global competencies such as
 - i. Problem-solving skills that are required to solve different types of Statistics

related problems with well-defined solutions, and tackle open-ended problems, that belong to the disciplinary-area boundaries;

- ii. Investigative skills, including skills of independent thinking of Statistics-related issues and problems;
- iii. Communication skills involving the ability to listen carefully, to read texts and reference material analytically and to present information in a concise manner to different groups/audiences of technical or popular nature;
- iv. Analytical skills involving paying attention to details and ability to construct logical Arguments using correct technical language related to Statistics and ability to translate them with popular language when needed;
- v. ICT skills;
- vi. Personal skills such as the ability to work both independently and in a group.

11. Undertake research projects by using research skills- preparation of questionnaire, conducting national sample survey, research projects using sample survey, sampling techniques.

12. Understand and apply principles of least squares to fit a model to the given data, study the association between the variables, applications of Probability Theory and Probability Distributions.

Assessment

Weightage for assessments (in percentage)

Type of Course	Formative Assessment / IA	Summative Assessment
Theory	40	60
Practical	25	25
Projects	30	70
Experiential Learning (Internships, etc.)	30	70

Model Program Structures for the Under-Graduate Programs in Universities and Colleges in Karnataka

Bachelor of Arts (Basic/ Hons.)/ Bachelor of Science (Basic/ Hons.) etc. with Statistics as Major with practical and any other subject as minor

Sem.	Discipline Core (DSC) (Credits) (L+T+P)	Discipline Elective (DSE) /Open Elective (OE) (Credits) (L+T+P)	Ability Enhancement Compulsory Courses (AECC), Languages (Credits)(L+T+P)		Skill Enhancement Courses (SEC)		Total Credits
					Skill based (Credits) (L+T+P)	Value based (Credits) (L+T+P)	
I	Descriptive Statistics (4+2) Discipline B1(4+2)	OE-1 (3)	L1-1 (3), L2-1 (3)(3+1+0 each)		SEC-1: Digital Fluency (2) (1+0+2)		23
II	Probability and Distributions (4+2) Discipline B2(4+2)	OE-2 (3)	L1-2(3), L2-2 (3) (3+1+0 each)	Environmental Studies (2)		Health & Wellness/ Social & Emotional Learning (2) (1+0+2)	25
Exit option with Certificate (48 credits)							
III	Calculus and Probability Distributions (4+2) Discipline B3(4+2)	OE-3 (3)	L1-3 (3), L2-3(3) (3+1+0 each)		SEC-2: Artificial Intelligence (2)(1+0+2)		23
IV	Statistical Inference-I (4+2) Discipline B4(4+2)	OE-4 (3)	L1-4 (3), L2-4(3) (3+1+0 each)	Constitution of India (2)		Sports/NCC/NSS etc. (2) (1+0+2)	25
Exit option with Diploma (96 credits)							
V	Statistical Inference-II (3+2) Matrix Algebra and Regression Analysis (3+2) Discipline B5(3+2)	DS-B Elective 1 (3)			SEC-3: Cyber Security (2) (1+0+2)	Ethics & Self Awareness (2) (1+0+2)?	20

VI	Analysis of variance and design of experiments (3+2) Discipline B6(3+2) Discipline B7(3+2)	DS-A Elective 1 (3)			SEC-4: Professional/ Societal Communication (2)		20
Exit option with Bachelor of Arts, B.A. / Bachelor of Science, B. Sc. Basic Degree (136 credits)							
Choose any one Discipline as Major							
VII	Sample Surveys and Statistics for National Development (3+2) Real Analysis (3+2) Probability Theory (4)	DS-A/B Elective 2(3) Res. Methodology (3)					20
VIII	Linear Algebra (4) Linear models and Design of Experiments (4)	DS-A/B Elective 3(3) DS-A/B Elective 4(3) Research Project (6)*					20
Award of Bachelor of Arts Honours, B.A. (Hons.)/ Bachelor of Science Honours, B.Sc. (Hons) degree in a discipline etc. (176 credits)							
IX	Multivariate Analysis (3)+ Practical (2) Decision Theory and Bayesian Inference (4) Distribution Theory (3) +Practical (2)	Statistics E-5(3:0:0) Research Methodology (3)					20
X	Stochastic Processes (4) Time Series Analysis (3) Machine Learning (4)	Statistics E-6 (3:0:0) Research Project (6)					20
Award of Master of Science Degree in Statistics							

Summary of Discipline Specific Courses (DSC)			
Semester	Course Code	Title of the Paper	Credits
I	ST 121	Descriptive Statistics	4
	ST 1P1	Practical based on ST 121	2
II	ST 221	Probability and Distributions	4
	ST 2P1	Practical based on ST 221	2
III	ST 321	Calculus and Probability Distributions	4
	ST 3P1	Practical based on ST 321	2
IV	ST 421	Statistical Inference-I	4
	ST 4P1	Practical based on ST 421	2
V	ST 5121	Statistical Inference-II	3
	ST 5P1	Practical based on ST 5121	2
	ST 5221	Matrix Algebra and Regression Analysis	3
	ST 5P2	Practical based on ST 5221	2
VI	ST 6121	Analysis of variance and design of experiments	3
	ST 6P1	Practical based on ST 6121	2
VII	ST 7121	Sample Surveys and Statistics for National Development	3
	ST 7P1	Practical based on ST 7121	2
	ST 7221	Real Analysis	3
	ST 7P2	Practical based on ST 7221	2
	ST 7321	Probability Theory	4
VIII	ST 8121	Linear Algebra	4
	ST 8221	Linear models and Design of Experiments	4

Semester	Course Code	Title of the Paper	Credits
IX	ST 9121	Multivariate Analysis	3
	ST 9P1	Practical based on ST 9121	2
	ST 9221	Decision Theory and Bayesian Inference	4
	ST 9321	Distribution Theory	3
	ST 9P2	Practical based on ST 9321	2
X	ST 0121	Stochastic Processes	4
	ST 0221	Time Series Analysis	3
	ST 0321	Machine Learning	2

List of Discipline Specific Electives (DSE)

<ul style="list-style-type: none"> • Actuarial Statistics • Advanced Statistical Inference • Analysis of Categorical Data • Analysis of Clinical Trials • Artificial Intelligence with R • Bayesian Inference • Bio-Statistics • Computational Statistics • Data Analytics with R/Python • Data Science: Multivariate Techniques with R /Python • Data Science with R/Python • Demography • Extreme value Theory • Econometrics 	<ul style="list-style-type: none"> • Financial Statistics • Multivariate Techniques • Nonparametric and Semiparametric Methods • Operations Research • Project Work • Reliability Analysis • Reliability and Statistical Quality Control • Statistical Learning and Data Mining with R/Python • Statistical Quality Control • Stochastic Models in Finance • Survival Analysis • Time Series Analysis • Sampling Theory and Applications
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List of Open Elective (OE) for first four semesters

<ul style="list-style-type: none"> • Statistical Methods • Business Statistics • Applied statistics • Biostatistics 	<ul style="list-style-type: none"> • Statistical Methods for Population Studies • Introduction to R Software • An introductory course on Operations Research
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Curriculum Structure for the Undergraduate Degree

Program: B.Sc.

Total Credits for the Program: 176

Starting year of implementation: 2021-22

Name of the Degree Program: B. Sc.

Discipline/Subject: Statistics (Major)

Program Articulation Matrix

This matrix lists only the core courses. Core courses are essential to earn the degree in that discipline/subject. They include courses such as theory, laboratory, project, internships etc. Elective courses may be listed separately

Sem ester	Title /Name of the course	Program outcomes that the course addresses (not more than 3 per course)	Pre-requisite course(s)	Pedagogy##	Assessment\$
1	Descriptive Statistics	PO1,PO2,PO 8	Mathematics of 12 th level	1. The course is taught using traditional chalk and talk method using problem solving through examples and exercises. 2. Students are encouraged to use resources available on open sources.	The assessment is done using continuous assessment through written test, open book examination, viva-voce, seminars, and group discussions.
1	Practical	PO5, PO6	Mathematics of 12 th level	The course is taught using Excel software and/or manually to carry out descriptive statistical analysis.	Assessment of learning through experiments
2	Probability and Distributions	PO7,PO9,PO 10	Mathematics of 12 th level	1. The course is taught using traditional chalk and talk method using problem solving through examples and exercises. 2. Students are encouraged to use resources available on open sources	The assessment is done using continuous assessment through written test, open book examination, viva-voce, seminars, and group discussions.
2	Practical	PO5, PO6	Mathematics of 12 th level	The course is taught using R programming software and/or manually to carry out descriptive statistical analysis	Assessment of learning through experiments

Pedagogy for student engagement is predominantly lectures. However, other pedagogies enhancing better student engagement to be recommended for each course. The list includes active learning/course projects/ problem or project-based learning/ case studies/self-study like seminar, term paper or MOOC

\$ Every course needs to include assessment for higher order thinking skills (Applying/ Analyzing/ Evaluating/ Creating). However, this column may contain alternate assessment methods that help formative assessment (i.e., assessment for learning).

Course Pre-requisite(s): II PUC with Mathematics

Course Outcomes (COs)

At the end of the course the student should be able to:

1. Acquire knowledge of introductory statistics, its scope and importance in various areas such as Medical, Engineering, Agricultural and Social Sciences etc.
2. Get knowledge of various types of data, their organization and evaluation of summary measures such as measures of central tendency and dispersion etc.
3. Perceive the knowledge of correlation, regression analysis, regression diagnostics, partial and multiple correlations.
4. Learn different of types of data reflecting independence and association between two or more attributes.
5. Develop ability to critically assess a standard report having graphics, probability statements.
6. Conceptualize the probabilities of events including frequentist and axiomatic approach. Simultaneously, they will learn the notion of conditional probability including the concept of Bayes' Theorem,
7. Get knowledge related to concept of discrete and continuous random variables and their probability distributions including expectation and moments,
8. Learn knowledge of important discrete and continuous distributions such as Binomial, Poisson, Normal distributions.
9. Acquire knowledge on R-programming in the descriptive statistics and probability models.

Course Articulation Matrix: Mapping of Course Outcomes (COs) with Program Outcomes (POs 1-12)

Course Outcomes (COs) / Program Outcomes (POs)	1	2	3	4	5	6	7	8	9	10	11	12
1. Knowledge of introductory statistics, its scope and importance in various areas such as Medical, Engineering, Agricultural and Social Sciences etc.	X	X			X	X						
2. Knowledge of various types of data, their organization and evaluation of summary measures such as measures of central tendency and dispersion etc.			X	X	X	X				X	X	
3. Knowledge of correlation, regression analysis, regression diagnostics, partial and multiple correlations.				X	X	X		X		X	X	
4. Knowledge of types of data reflecting independence and association between two or more attributes				X	X	X				X		X
5. Develop ability to critically assess a standard report having graphics, probability statements.					X	X	X		X			
6. Knowledge to conceptualize the probabilities of events including frequentist and axiomatic approach. Simultaneously, they will learn the notion of conditional probability including the concept of Bayes' Theorem.					X	X			X	X		
7. Knowledge related to concept of discrete and continuous random variables and their probability distributions including expectation and moments.					X	X			X	X		
8. Knowledge of important discrete and continuous distributions such as Binomial, Poisson, Normal, distributions.					X	X			X	X		
9. Knowledge on R-programming in the descriptive statistics and probability models.					X	X			X	X		

Course Articulation Matrix relates course outcomes of course with the corresponding program outcomes whose attainment is attempted in this course. 'X' in the intersection cell indicates that particular course outcome addresses that particular program outcome

Bachelor of Science (Basic/Hons.) in Statistics

First Semester

ST – 121: Descriptive Statistics

Semester	I
Paper Code	ST-121
Paper Title	Descriptive Statistics
Number of teaching hours per week	04
Total number of teaching hours per semester	56
Number of credits	04
Formative Assessment Marks	40
Summative Assessment Marks	60

Unit – 1: Introduction to Statistics

13 Hours

Statistics: Definition and scope. Concepts of statistical population and sample. Data: quantitative and qualitative, cross sectional and time-series, discrete and continuous. Scales of measurement: nominal, ordinal, interval and ratio. Sampling theory concepts: (SRS, Stratified, Systematic and Cluster sampling methods (Definitions only). Presentation of data: tabular and graphical. Frequency distributions, cumulative frequency distributions and their graphical representations. Stem and leaf displays.

Unit – 2: Univariate Data Analysis

18 Hours

Measures of Central Tendency: Mean, weighted mean, trimmed mean, Median, Mode, Geometric and harmonic means, properties, merits and limitations, relation between these measures. Measures of Dispersion: Range, Quartile deviation, Mean deviation, Standard deviation and their relative measures. Moments, Skewness and Kurtosis. Quantiles and measures based on them. Box Plot. Outliers. Chebyshev's inequality, normal data sets.

Unit – 3: Bivariate Data Analysis

15 Hours

Bivariate Data, Scatter plot, Correlation, Karl Pearson's correlation coefficient, Rank correlation – Spearman's and Kendall's measures. Concept of errors, Principle of least squares, fitting of polynomial and exponential curves. Simple linear regression and its properties. Fitting of linear regression line and coefficient of determination.

Unit –4: Multivariate Data Analysis

10 Hours

Analysis of Categorical Data: Contingency table, independence and association of attributes, measures of association - odds ratio, Pearson's and Yule's measure, Multivariate data sets and its visualization, illustration of mean vector and dispersion matrix, Multiple linear regression, multiple and partial correlation coefficients (Only for 3 variables). Residual error variance.

References

1. Agresti, A. (2010): Analysis of Ordinal Categorical Data, 2nd Edition, Wiley.
2. Anderson T.W. and Jeremy D. Finn (1996). The New Statistical Analysis of Data, Springer
3. Freedman, D., Pisani. R and Purves. R. (2014), Statistics, 4th Edition, W. W. Norton & Company.
4. Gupta, S.C. (2018), Fundamental of Statistics, Himalaya Publishing House, 7th Edition.
5. Gupta S.C. and V.K. Kapoor (2020), Fundamental of Mathematical Statistics, Sultan Chand and Co. 12th Edition.
6. Hogg, R. V. McKean J. W. and Craig, A. T. (2012), Introduction to Mathematical Statistics, Pearson 7th Edition.
7. Joao Mendes Moreira, Andre C P L F de Carvalho, Tomas Horvath (2018), General Introduction to Data Analytics, Wiley.
8. Johnson, R.A. and Bhattacharyya, G.K. (2006), Statistics: Principles and methods. 5th Edition, John Wiley & Sons, New York.
9. Medhi, J. (2005), Statistical Methods, New Age International.
10. Ross, S.M. (2014), Introduction to Probability and Statistics for Engineers and Scientists, 5th Edition, Academic Press.
11. Tukey, J.W. (1977), Exploratory Data Analysis, Addison-Wesley Publishing Co. References

Pedagogy

1. The course is taught using traditional chalk and talk method using problem solving through examples and exercises.
2. Students are encouraged to use resources available on open sources.

MODEL BLUEPRINT		
Code number:		ST – 121
Title of the paper:		Introduction to Statistics and Probability
Unit number	Number of hrs	Total marks
1	13	20
2	18	28
3	15	23
4	10	15
Total	55	86
Maximum marks for the paper (Excluding bonus questions)		60

Practical I

ST – 1P1 – Practical on ST – 121

Number of teaching hours per week	04
Total number of teaching hours per semester	52
Number of credits	02
Formative Assessment Marks	25
Summative Assessment Marks	25

Computing all the practical manually and using Excel

1. Presentation of data by frequency tables, diagrams and graphs, stem and leaf, partition values.
2. Arithmetic Mean (AM), geometric mean, harmonic mean, weighted AM, trimmed mean, corrected mean.
3. Mode, median, partition values.
4. Absolute and relative measures of dispersion, Box plots.
5. Problems on moments, skewness and kurtosis.
6. Fitting of curves by least squares method.
7. Product moment correlation coefficient and rank correlation.
8. Regression of two variables.
9. Multivariate Descriptive statistics, mean Vector, dispersion matrix correlation matrix, Partial and Multiple correlation.
10. Problems on Association of attributes.

Bachelor of Science (Basic/Hons.) in Statistics
Second Semester

ST 221: Probability and Distributions

Semester	II
Paper Code	ST-221
Paper Title	Probability and Distributions
Number of teaching hours per week	04
Total number of teaching hours per semester	56
Number of credits	04
Formative Assessment Marks:	40
Summative Assessment Marks:	60

Unit –1: Probability

15 Hours

Random experiment, sample space and events, algebra of events. Definitions of Probability- Classical, statistical, subjective and axiomatic approaches – illustrations and applications, Addition Theorem, Conditional probability, independence of events and multiplication Theorem, Total probability rule, Bayes theorem and applications.

Unit –2: Random Variables and Mathematical Expectation

14 Hours

Definitions of discrete and continuous random variables, Distribution function, probability mass and density functions – properties and illustrations, Expectation of a random variable and Properties of expectation, Moments and moment generating function – properties and uses.

Unit –3: Standard Distributions

16 Hours

Bernoulli, Binomial, Poisson, Geometric distributions– mean, variance, moments and m. g. f. recursive relations for probabilities and moments of Binomial and Poisson distributions, Uniform, Exponential and Normal distribution: Mean and Variance, m. g. f. Memoryless property, Area property of normal distribution. Fitting of distributions and to assessing its goodness of fit (Graphically).

Unit –4: Data Analysis Using R

11 Hours

Introduction to R: Installation, command line environment, overview of capabilities, brief mention of open-source philosophy. R as a calculator: The four basic arithmetic operations. Use of parentheses nesting up to arbitrary level. The power operation. Evaluation of simple expressions. Quotient and remainder operations for integers. Standard functions, e.g., sin, cos, exp, log. The different types of numbers in R: Division by zero leading to Inf or -Inf. NaN. NA. No need to go into details. Variables. Creating a vector using c(), seq() and colon operator. How functions map over vectors. Functions to summarize a vector: sum, mean, sd, median etc. Extracting a subset from the vector (by index, by property). R as a graphing calculator: Introduction to plotting. Plot(), lines(), abline(). No details about the graphics parameters except colour and line width. Barplot, Pie chart and Histogram. Box plot. Scatter plot and simple linear regression using lm(y~x). Problems on discrete and continuous probability distributions

References

1. Dudewitz. E.J. and Mishra. S. N. (1998), Modern Mathematical Statistics. John Wiley.
2. Goon A.M., Gupta M.K., Das Gupta. B. (1991), Fundamentals of Statistics, Vol. I, World Press, Calcutta.
3. Gupta. S.C and V.K. Kapoor (2020), Fundamentals of Mathematical Statistics, Sultan Chand and Co, 12th Edition.
4. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009), Probability and Statistical Inference, Seventh Edition, Pearson Education, New Delhi.
5. Mood, A.M., Graybill, F.A. and Boes, D.C. (2007), Introduction to the Theory of Statistics, 3rd Edition. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
6. Ross, S. (2002), A First Course in Probability, Prentice Hall.
7. Sudha G. Purohit, Sharad D. Gore, Shailaja R Deshmukh, (2009), Statistics using R, Narosa Publishing House.
8. R for beginners by Emmanuel Paradis (freely available at https://cran.r-project.org/doc/contrib/Paradisrdebuts_en.pdf)

Pedagogy

1. The course is taught using traditional chalk and talk method using problem solving through examples and exercises.
2. Students are encouraged to use resources available on open sources.

MODEL BLUEPRINT		
Code number:		ST – 221
Title of the paper:		Probability and Distribution
Unit number	Number of hrs	Total marks
1	15	23
2	14	21
3	16	25
4	11	17
Total	56	86
Maximum marks for the paper (Excluding bonus questions)		60

Practical II

ST – 2P1 – Practical on ST – 221

Number of teaching hours per week	04
Total number of teaching hours per semester	52
Number of credits	02
Formative Assessment Marks	25
Summative Assessment Marks	25

Computing all the practical manually and using Excel/R

1. Two exercises on Descriptive statistics (Presentations, Summarizations, correlations, regression and Graphs using R)
2. Computing probability: using addition and multiplication theorems.
3. Conditional probability and Bayes' theorem.
4. Problems on pmf, expectation, variance, quantiles, skewness, kurtosis (Discrete Case).
5. Problems on pdf, expectation, variance, quantiles, skewness, kurtosis (Continuous case).
6. Problems on discrete probability distributions (Binomial, Poisson, Geometric)
7. Problems on Uniform, Exponential and Normal probability distributions
8. Computation of moments and Moment generating functions (Discrete and Continuous Case).
9. Fitting of distributions (Binomial, Poisson, Geometric, Uniform, Exponential, Normal)
10. Generation of random samples. (Binomial, Poisson, Geometric, Uniform, Exponential, Normal)

Bachelor of Science (Basic/Hons.) in Statistics

Third Semester

ST 321: Calculus and Probability Distributions

Semester	III
Paper Code	ST-321
Paper Title	Calculus and Probability Distributions
Number of teaching hours per week	04
Total number of teaching hours per semester	56
Number of credits	04
Formative Assessment Marks:	40
Summative Assessment Marks:	60

Unit –1: Limits, Continuity, and Differentiability.

10 Hours

Introduction to Sets and functions, types of functions, properties of functions, Monotonicity, convexity and concavity, Bounded functions. recapitulation and extension of limits and continuity, differentiability. Limit inferior and Limit superior, L'Hopital's rule, mean value theorems (Lagrange and Cauchy's) with examples, Taylor's Theorem, Maclaurin's series with the application. (Statement only), Introduction to nth derivative.

Unit –2: Sequences, Series, and Integration

12 Hours

Sequences and series of real numbers, Bounded sequences, Convergent and divergent sequences, Limit of sequences with their properties.

Series – Definition of infinite series, tests for convergence of infinite series - properties of series of positive terms - Geometric series Tests for convergence of series -p- series - comparison of series Cauchy's root Test -D Alembert's test. Raabe's test

Introduction to proper and Improper Integrals, types of improper Integrals, evaluation of improper Integrals, Beta and Gamma Integrals with their properties. –Maxima and Minima of functions of two variables. Method of Lagrange multipliers.

Unit –3: Basics of Sampling and Exact sampling distributions.

12 Hours

Concepts of population and sample. Sampling distributions and Standard error of a statistic and its uses. Sampling distribution of the sample means, sample variance, and their independence under normality assumption. Chi-square, t, and F statistic under normality assumption. Generation of random numbers from standard distributions.

Unit – 4: Discrete and Continuous Probability distributions and their applications. **22 Hours**

Negative-Binomial, Hypergeometric distributions- Definitions through p.m.f's, mean, variance, moments, and MGF. Limiting form of Hypergeometric and Binomial distributions, relationship between geometric and Negative binomial distributions.

Gamma, Beta (First and Second kind), Laplace and Cauchy distributions – definition through p.d.f.s. Mean, variance, moments, and MGF with their properties.

Applications of discrete and continuous distribution through real life examples.

Chi-square, t and F distributions- Definitions through p.d.f's, mean, variance properties and uses.

References

1. Ghorpade.S.R., and Limaye. B.V., (2006): A course in Calculus and Real Analysis, Springer Series, New York.
2. Ajith Kumar and S. Kumaresan., (2014): A basic course in Real Analysis, CRC Press, Taylor and Francis, United Kingdom.
3. Shanti Narayan and Mittal. P.K., (2005): A course of Mathematical Analysis, S. Chand Publishers, New Delhi.
4. Rohatgi. V.K. and A.K. Md. Ehsanes Saleh (2002). An Introduction to Probability theory and Mathematical Statistics. John Wiley. (WSE)
5. Bhattacharya and N.L. Johnson (1986): Statistical concepts. John Wiley.
6. Miller. I and Miller. M (2014) John E. Freund's Mathematical Statistics with Applications, Pearson.

Pedagogy

1. The course is taught using traditional chalk and talk method using problem solving through examples and exercises.
2. Students are encouraged to use resources available on open sources.

MODEL BLUEPRINT		
Code number:		ST – 321
Title of the paper:		Calculus and Probability Distribution
Unit number	Number of hrs	Total marks
1	10	15
2	12	18
3	12	18
4	22	35
Total	56	86
Maximum marks for the paper (Excluding bonus questions)		60

Practical III

ST – 3P1 – Practical on ST – 321

Number of teaching hours per week	04
Total number of teaching hours per semester	52
Number of credits	02
Formative Assessment Marks	25
Summative Assessment Marks	25

Computing all the practical manually and using Excel/R

1. Practical on Sequences and Series
2. Numerical evaluation of some special functions.
3. Drawing random samples and construction of sampling distribution of sample mean and sample variance
4. Drawing random samples and construction of sampling distribution of sample mean and sample variance (using MS Excel and R)
5. Applications of Negative binomial distribution and Hypergeometric (Computation of probabilities, fitting)
6. Fitting Negative Binomial, Hypergeometric using MS Excel and R
7. Computation of probabilities and plotting pmf, cdf using MS-Excel and R (Negative Binomial, Hypergeometric)
8. Computation of probabilities and plotting pdf, cdf using MS-Excel and R (Gamma, Beta, Cauchy, Laplace)
9. Generation of random observations from standard discrete distributions
10. Generation of random observations from standard continuous distributions

Bachelor of Science (Basic/Hons.) in Statistics

Fourth Semester

ST 421: Statistical Inference - I

Semester	IV
Paper Code	ST-421
Paper Title	Statistical Inference - I
Number of teaching hours per week	04
Total number of teaching hours per semester	56
Number of credits	04
Formative Assessment Marks:	40
Summative Assessment Marks:	60

Unit -1: Family of Distributions and Theory of Point Estimation:

18 Hours

Family of distributions: Power Series family, single parameter exponential family, K - parameter exponential family, location - Scale family, Pitman family Definitions, examples and applications with case studies.

Point Estimation - Concepts of estimator and estimate, criteria of a good estimator - Unbiasedness, Consistency, sufficient conditions for consistency, Invariance property of consistent estimator, Sufficient Statistic - Statement of Neyman – Factorization theorem, minimum variance unbiased estimator, Efficiency and Relative efficiency, mean square error. (Problems on estimation from Bernoulli, Binomial, Poisson, Geometric, Negative Binomial, Uniform, Normal and Exponential distributions only).

Unit -2: Methods of Point Estimation:

12 Hours

Methods of Point Estimation: Maximum likelihood estimator (MLE) and method of moments: Properties, Illustration for non-uniqueness and invariance property of MLE. Estimation of parameters for Bernoulli, Binomial, Poisson, Geometric, Negative Binomial, Normal, Exponential, Continuous Uniform distributions.

Unit - 3: Interval Estimation:

14 Hours

Confidence Interval, Confidence coefficient, Pivotal quantity method of constructing Confidence Intervals, construction of confidence intervals for the mean, the difference between two means, variance and ratio of variances, proportion, the difference between proportions, and correlation coefficient.

Unit - 4: Testing of Hypotheses:

12 Hours

Definition of Statistical hypotheses and types - null and alternative, simple and composite hypotheses. Type-I and Type-II Errors, size of the test, level of significance, power of the test, and power function. Test function, Randomized and non-randomized test (definition only). Critical region. P-value, its interpretation. Illustration for a large sample test of the single mean.

References:

1. Freund J.E. (2001): Mathematical Statistics, Prentice Hall of India.
2. Goon A.M., Gupta M.K., Das Gupta.B. (1991): Fundamentals of Statistics, Vol. I, World Press, Calcutta.
3. Hogg R.V. and Tannis E.A. (1988): Probability and Statistical Inference, Collier MacMillan.
4. Hodges J.L and Lehman E.L (1974): Basic Concepts of Probability and Statistics, Holden-Day.
5. Mood A.M, Graybill F.A and Boes D.C. (1974): Introduction to the Theory of Statistics, McGraw Hill.
6. Gupta. S.C. and V.K.Kapoor (2001): Fundamentals of Mathematical Statistics. Sultan Chand & Co.
7. Bhattacharya and Johnson (1986): Statistical Concepts, Wiley Int. Ed.
8. Rohatgi. V.K. and A.K. Md. Ehsanes Saleh (2002). An Introduction to Probability theory and Mathematical Statistics. John Wiley (WSE).
9. Ross S.M: Introduction to Probability and Statistics., John Wiley & Sons

Pedagogy

1. The course is taught using traditional chalk and talk method using problem solving through examples and exercises.
2. Students are encouraged to use resources available on open sources.

MODEL BLUEPRINT		
Code number:		ST – 421
Title of the paper:		Statistical Inference - I
Unit number	Number of hrs	Total marks
1	18	28
2	12	18
3	14	22
4	12	18
Total	56	86
Maximum marks for the paper (Excluding bonus questions)		60

Practical IV

ST – 4P1 – Practical on ST – 421

Number of teaching hours per week	04
Total number of teaching hours per semester	52
Number of credits	02
Formative Assessment Marks	25
Summative Assessment Marks	25

Computing all the practical manually and using Excel/R

1. Properties of estimators on unbiasedness, consistency and efficiency.
2. Comparison of estimators by plotting mean square error using MS-Excel and R.
3. Estimation of parameters by Maximum Likelihood method.
4. Estimation of parameters by Method of Moments.
5. Estimation of parameters by Maximum Likelihood method and Method of Moments using R & EXCEL.
6. Construction of confidence intervals - I (large samples).
7. Construction of confidence intervals - II (small samples).
8. Construction of confidence intervals using R & MS-Excel.
9. Testing of Hypothesis - I (Formulation of hypotheses, understanding types of hypotheses, understanding types of tests).
10. Testing of Hypothesis - II (Understanding Type I error and Type II Error)

Bachelor of Science (Basic/Hons.) in Statistics

Fifth Semester

ST 5121: Statistical Inference - II

Semester	V
Paper Code	ST-5121
Paper Title	Statistical Inference – II
Number of teaching hours per week	03
Total number of teaching hours per semester	42
Number of credits	03
Formative Assessment Marks:	40
Summative Assessment Marks:	60

Unit – 1: MP and UMP tests

16 Hours

Most Powerful (MP) test. Statement of Neyman – Pearson Lemma and its applications. MP test for parameters of Bernoulli, Binomial and Normal distributions.

Monotone likelihood ratio (MLR) property. Uniformly most powerful (UMP) test. Statement of the theorem on UMP test for testing one-sided hypothesis for distributions with MLR property. (Only parameter of Bernoulli and mean of Normal Distribution)

Unit – 2: Likelihood Ratio tests

6 Hours

Likelihood ratio tests (LRT) and its properties. LRTs for mean and variance of normal distribution (one-sample problem), LRT for the mean of Exponential distribution.

Unit -3: Tests of Significance:

10 Hours

Large and small sample tests of significance. Tests for proportions and differences between proportions, Tests for single mean, equality of two means, single variance, and the ratio of two variances. Tests for correlation coefficient and regression coefficients (only slope and intercept (t-test)). Fisher's Z-transformation and its applications (test for non-zero correlation coefficient). Analysis of categorical data- contingency table, Chi-square test for independence of attributes in a contingency table, Chi-square test for goodness of fit, and equality of several proportions using Chi-square test.

Unit – 4: Non-Parametric tests:

10 Hours

Need for distribution-free tests - non-parametric tests. one sample and two samples sign tests, Wilcoxon signed-rank test, Median test, Wald Wolfowitz run test, Mann Whitney Wilcoxon test, run test for randomness, test for independence based on Spearman's rank correlation coefficient (small and large samples), Kolmogorov-Smirnov one-sample test and two-sample test, Normal probability plot and QQ Plot.

Reference:

1. Rohatgi. V.K. and A.K. Md. Ehsanes Saleh (2002). An Introduction to Probability theory and Mathematical Statistics. John Wiley (WSE).
2. Hogg R.V. and Tannis E.A. (1988): Probability and Statistical Inference, Collier MacMillan.
3. Mukhopadhyay. P (1996). Applied Statistics. Calcutta Publishing House.
4. Gupta. S.C. and V.K.Kapoor (2001): Fundamentals of Mathematical Statistics. Sultan Chand & Co.
5. Gopal K. Kanji (2006), 100 Statistical tests, 3rd Edition, Sage Publications
6. Purohit S.G. et.al. Statistics using R
7. Dudewicz. E.J. and Mishra. S.N. (1980). Modern Mathematical Statistics. John Wiley.
8. Kale B.K (2005) A First Course on Parametric Inference, the Narosa 2nd Edition.
9. Randles R.H and Wolfe DA (1979): Introduction to the Theory of nonparametric Statistics, John Wiley
10. John Verzani (2005): Using R for Introductory Statistics, CHAPMAN & HALL/CRC
11. Venables W.N., Smith D.M., and the R-development core team, An Introduction to R

Pedagogy

1. The course is taught using traditional chalk and talk method using problem solving through examples and exercises.
2. Students are encouraged to use resources available on open sources.

MODEL BLUEPRINT		
Code number:		ST – 5121
Title of the paper:		Statistical Inference – II
Unit number	Number of hrs	Total marks
1	16	33
2	06	12
3	10	21
4	10	20
Total	42	86
Maximum marks for the paper (Excluding bonus questions)		60

Practical V

ST – 5P1 – Practical on ST – 5121

Number of teaching hours per week	04
Total number of teaching hours per semester	52
Number of credits	02
Formative Assessment Marks	25
Summative Assessment Marks	25

Computing all the practical manually and using Excel/R

1. MP test, UMP test and LR test for parameters of Bernoulli distribution & Normal Distributions
2. Tests concerning means and proportions (small and large sample)
3. Tests concerning variances (small and large sample)
4. Tests for correlation coefficients and Regression coefficient (slope and intercept)
5. Tests for Independence of attributes and equality of many proportions
6. Tests for goodness of fit. (Uniform, Binomial, Poisson and Normal)
7. Small and Large sample test using MS Excel and R
8. Nonparametric tests – 1 (for single and related samples - sign test and Wilcoxon signed rank test, Kolmogorov Smirnov test and one sample runs test)
9. Nonparametric tests – 2 (for two independent samples (Median test, Wilcoxon Mann Whitney - U test, Wald - Wolfowitz's runs test)
10. Tests for Normality, Histogram, QQ Plot using R

Bachelor of Science (Basic/Hons.) in Statistics

Fifth Semester

ST 5221: Matrix Algebra and Linear Regression

Semester	V
Paper Code	ST-5221
Paper Title	Matrix Algebra and Linear Regression
Number of teaching hours per week	03
Total number of teaching hours per semester	42
Number of credits	03
Formative Assessment Marks:	40
Summative Assessment Marks:	60

Unit- 1: Vector Spaces and Matrices

10 Hours

Transpose, determinant, inverse, rank, and the trace of a matrix, Hassenberg matrix

Vector spaces, and subspaces, examples of vector spaces on \mathbb{R} , basis and dimension of a vector space, rank nullity theorem

Linear independence of vectors, inner product and orthogonal vectors, Gram-Schmidt orthogonalization process (Concept only)

Unit- 2: Eigen Values and Eigen Vectors

8 Hours

Eigenvalues and Eigenvectors, Cayley-Hamilton theorem, algebraic and geometric multiplicities, rank multiplicity theorem. Quadratic forms, congruent transformations, congruence of symmetric matrices, canonical reduction and orthogonal reduction of real quadratic forms, nature of quadratic forms, simultaneous reduction of quadratic forms.

Unit- 3: Simple and Multiple Regression

12 Hours

Simple linear regression and Multiple Linear Regression Models: Assumptions, Least-squares estimates and their properties, Model fitting, residuals, Coefficient of determination. Tests for significance of regression, tests on individual regression coefficients. Confidence intervals in multiple linear regression and prediction of a new observation.

Unit- 4: Model Adequacy

12 Hours

Different methods of variable selections – forward, backward, step-wise (only concept), Model Adequacy – Residual Analysis, tests for normality – QQ Plot. Introduction to Heteroscedasticity, Multicollinearity, and Autocorrelation, measures of identifying above situations, and remedial measures. Introduction to logistic regression

Reference:

1. Graybill F. A. (1969): An Introduction to Linear Statistical Models.
2. S. Kumaresan (2000) Linear Algebra: A Geometric Approach, PHI
3. Draper N. R. and Smith H. (2003): Applied Regression Analysis, 3rd Ed., John Wiley.
4. Hosmer D. N. and Lemeshow's (2013): Applied Logistic Regression, 3rd Ed., John Wiley.
5. Montgomery D. C., Peck E. A. and Vining G. G.(2003): Introduction to Linear regression Analysis, 3rd Ed., John Wiley.

Pedagogy

1. The course is taught using traditional chalk and talk method using problem solving through examples and exercises.
2. Students are encouraged to use resources available on open sources.

MODEL BLUEPRINT		
Code number:		ST – 5221
Title of the paper:		Matrix Algebra and Linear Regression
Unit number	Number of hrs	Total marks
1	10	20
2	8	16
3	12	25
4	12	25
Total	42	86
Maximum marks for the paper (Excluding bonus questions)		60

Practical VI

ST – 5P2 – Practical on ST – 5221

Number of teaching hours per week	04
Total number of teaching hours per semester	52
Number of credits	02
Formative Assessment Marks	25
Summative Assessment Marks	25

Computing all the practical manually and using Excel/R

1. Linear Independence and Linear dependence of a set of vectors.
2. Determinants, Inverse and Rank of a matrix.
3. Verification of Cayley-Hamilton theorem. Eigenvalues and Eigenvectors of a matrix.
4. Simple linear regression
5. Multiple linear regression
6. Fitting Regression model for Multivariate Data using MS-Excel and R
7. Regression analysis Model Adequacy-Residual Analysis, t-test, and F-test
8. Regression analysis with Multicollinearity and variable selection techniques.
9. Regression analysis with Heteroscedasticity.
10. Regression analysis with Autocorrelation

Bachelor of Science (Basic/Hons.) in Statistics

Sixth Semester

ST 6121: Analysis of Variance and Design of Experiment

Semester	V
Paper Code	ST-6121
Paper Title	Analysis of Variance and Design of Experiment
Number of teaching hours per week	03
Total number of teaching hours per semester	42
Number of credits	03
Formative Assessment Marks:	40
Summative Assessment Marks:	60

Unit- 1: Understanding designs

5 Hours

Experimental designs: Role, historical perspective, terminology: Treatments, Experimental units & Blocks, Experimental error, Basic principles of Design of Experiments. Randomization - Blinded experiments. Uniformity trials, fertility contour maps, choice of size and shape of plots and blocks in Agricultural experiments. Real-time industrial application with case studies.

Unit – 2: Analysis of Variance

12 Hours

Analysis of Variance: Definition and assumptions. Analysis of variance - fixed-effects and random-effects models. Analysis of one-way and two-way classified data, testing of hypothesis, and ANOVA tables. Multiple comparison tests-Least significant difference, Tuckey's test.

Unit-3: Design of Experiment:

15 Hours

Implementation of Basic principles of design. Completely randomized design, randomized block design, and Latin square design - assumptions, layout, model, derivation of least squares estimates of parameters, hypotheses testing, and ANOVA table.

The efficiency of RBD over CRD and LSD over RBD. Missing plot technique- Estimation of single missing observation in RBD and LSD, analysis.

Unit-4: Factorial Experiments:

10 Hours

Concept of factorial designs - 22 and 23 factorial experiments - Main effects and interactions. Their best Estimates, orthogonal contrasts. Yates's method of computing factorial effect totals. Complete and partial confounding in 23-factorial experiments - analysis when the underlying design is RBD.

Reference:

1. Cochran, W.G. and Cox, G.M. (1959): Experimental Design. Asia Publishing House.
2. Das, M.N. and Giri, N.C. (1986): Design and Analysis of Experiments. Wiley Eastern Ltd.
3. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics. Vol. II, 8thEdn. World Press, Kolkata.
4. Kempthorne, O. (1965): The Design and Analysis of Experiments. John Wiley.
5. Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley.
6. Wu, C. F. J. And Hamada, M. (2009). Experiments, Analysis, and Parameter Design Optimization (Second edition), John Wiley.
7. Dean, A.M. and Voss, D. (1999): Design and Analysis of Experiments. Springer Texts in Statistics.

Pedagogy

1. The course is taught using traditional chalk and talk method using problem solving through examples and exercises.
2. Students are encouraged to use resources available on open sources.

MODEL BLUEPRINT		
Code number:		ST – 6121
Title of the paper:		Analysis of Variance and Design of Experiment
Unit number	Number of hrs	Total marks
1	5	10
2	12	25
3	15	31
4	10	20
Total	42	86
Maximum marks for the paper (Excluding bonus questions)		60

Practical VII

ST – 6P1 – Practical on ST – 6121

Number of teaching hours per week	04
Total number of teaching hours per semester	52
Number of credits	02
Formative Assessment Marks	25
Summative Assessment Marks	25

Computing all the practical manually and using Excel/R

1. Completely Randomized Design & Analysis of one-way classification data
2. Randomized Block Design & Analysis of two-way classification data
3. Analysis of one way and two-way classification data using MS Excel and R
4. Latin Square Design
5. Multiple comparison tests
6. Missing plot techniques
7. Analysis of 2^2 factorial experiments using RBD layout.
8. Analysis of 2^3 factorial experiments using RBD layout.
9. Analysis of 2^3 factorial experiments using RBD layout. (Complete confounding)
10. Analysis of 2^3 factorial experiments using RBD layout. (Partial confounding)

Bachelor of Science (Basic/Hons.) in Statistics

Sixth Semester

STDE A – 6221: Statistical Methods for Quality Management

Semester	VI
Paper Code	STDE A – 6221
Paper Title	Statistical Methods for Quality Management
Number of teaching hours per week	03
Total number of teaching hours per semester	42
Number of credits	03
Formative Assessment Marks:	40
Summative Assessment Marks:	60

Unit-1: Basics of Statistical Quality Control:

09 Hours

Introduction-quality, quality control, Quality assurance, quality costs. Seven QC tools. Chance and assignable causes of variation. Introduction to quality standards –BIS and ISO, Six-sigma and Total Quality Management, Deming’s 14-point principles. Statistical Quality Control (SQC) -. Aims and objectives, Process control and product control. Control charts and basis for its construction, Probability and k sigma limits, action and warning limits. Rational subgroups.

Unit-2: Control Charts for variables and attributes:

11 Hours

Derivation of control limits, construction and interpretation of mean, range and standard deviation charts. Revised control charts. Criteria for detecting lack of control, OC and ARL for mean and range charts. Need for control charts for attributes, derivation of control limits, basis, construction and interpretation of np-chart, p-chart, stabilized p-chart, c-chart, u-chart and their applications.

Unit-3: Process Capability:

07 Hours

Natural tolerance limits and specification limits. Process capability study-process capability and Process capability ratio C_p , C_{pk} , C_{pm} . Acceptance sampling-Introduction. Sampling inspection, 100 percent inspection and Rectifying inspection. AQL, LTPD, Producer’s risk and consumer’s risk.

Unit- 4: Lot Acceptance Sampling:

15 Hours

Acceptance Sampling plans – single and double sampling plans by attributes. Derivation of O.C, A.O.Q, A.S.N and A.T.I, functions for single and double sampling plans. Construction of single sampling plans by attributes given AQL, LTPD, producer’s risk, consumer’s risk. Sequential Probability Ratio Test; concept and operational definition. Determination of stopping bounds A and B, OC and ASN functions of SPRT for testing the mean of a normal distribution with known variance. Statement of the optimal property of SPRT.

Reference:

1. Grant, E.L and Leavenworth, R.S (1988): Statistical Quality control. 6th edition, McGrawHill.
2. Gupta, R.C: Statistical Quality control. (Khanna Pub. Co.)
3. Montgomery, D.C (1985): Introduction to Statistical Quality control. (Wiley Int. Edn.)
4. Goon, A.M et.al.: Fundamentals of Statistics Vol II (World Press, Calcutta)
5. Gupta, S.C and V.K. Kapur: Fundamentals of Applied Statistics. (Sultan Chand and Co.)
6. John, S.Oakland and Followell, R.F (1990): Statistical Process Control. (East West Press, India)
7. Wetherill, G.B and D.W. Brown: Statistical Process Control theory and practice. (Chapman and Hall)
8. Mahajan, M (2001): Statistical Quality Control. Dhanpat Rai & Co. (P) Ltd.
9. Donne, C.S. (1997): Quality. Prentice Hall.
10. Sinha S.K. and Kale B.K. (1980) Life testing and Reliability (New age)
11. Duncan A.J (1974): Quality Control and Industrial Statistics, Taraporewala and Sons.
12. John Verzani (2005): Using R for Introductory Statistics, CHAPMAN & HALL/CRC
13. Issa Bass (2007), Six Sigma Statistics with EXCEL and MINITAB, McGraw Hill
14. Ruth K. Meyer, David D. Krueger, (1998), A Minitab Guide to Statistics, Prentice Hall,
15. <https://cran.r-project.org/web/packages/qcc/qcc.pdf>

Pedagogy

1. The course is taught using traditional chalk and talk method using problem solving through examples and exercises.
2. Students are encouraged to use resources available on open sources.

MODEL BLUEPRINT		
Code number:		STDE – 6221
Title of the paper:		Operations Research
Unit number	Number of hrs	Total marks
1	9	18
2	11	23
3	7	14
4	15	31
Total	42	86
Maximum marks for the paper (Excluding bonus questions)		60

Bachelor of Science (Basic/Hons.) in Statistics

Sixth Semester

STDE B – 6221: Operations Research

Semester	VI
Paper Code	STDE B – 6221
Paper Title	Operations Research
Number of teaching hours per week	03
Total number of teaching hours per semester	42
Number of credits	03
Formative Assessment Marks:	40
Summative Assessment Marks:	60

Unit-1: Introduction to O.R and L.P.P, T.P., and A.P.:

17 Hours

Definition and scope of operations research (OR). Modeling and solution.

Linear programming problem (L.P.P) – Definition, Standard and canonical forms. Formulation of LPP. Basic solutions, Degenerate and non-degenerate solution. Fundamental theorem of LPP. Graphical solution and Simplex algorithm for solving an LPP, Criteria for unbounded, multiple and infeasible solutions. Artificial variable, Charnes’ Big- M Method.

Transportation problem: Mathematical formulation, finding an initial basic feasible solution by North West corner rule, and Vogel’s method. Test for optimality by u-v method, Transportation algorithm (MODI method). Problem of Degenerate solution and its resolution

Assignment problem: Mathematical formulation and Hungarian algorithm, Job sequencing, optimal sequence of N jobs on two and three machines

Unit-2: Statistical Decision Theory and Game theory:

07 Hours

Statistical decision problem and essential elements. Decision making under uncertainty and risk. Game theory- Basic concepts. Two-person zero sum game, Pure and mixed strategies. Maximin–Minimax principle, Games with saddle point. Principle of dominance. Games without Saddle point. -mixed strategies, Determination of optimum solution for (2x2) game. Solution by graphical method for (2xn) and (mx2) games.

Unit-3: Network analysis and Inventory Theory:

13 Hours

Basic elements of Network, Drawing of project network. Project planning with CPM and PERT. Critical path calculation. Critical path, slack time, floats. PERT three estimate approach. Calculation of probabilities of completing a Project within a specified period.

Description of an inventory system, Inventory costs. Demand, lead time and reorder level. Inventory models. EOQ model with and without shortages, P – system and Q – system of Inventory

Unit-4: Queuing theory:

05 Hours

Basic elements, description of a queuing system and measures of effectiveness. statement of steady state solution of M/M/1 queuing system. Waiting time distributions. Little’s formula. Derivation of expressions for Queue length, and system size(length) and waiting times. Description of M/M/C queuing system.

Reference:

1. Kanthiswarop, Manmohan and P.K. Gupta (2003) Operations Research. Sultan Chand & Co.
2. S D Sharma, Operations Research: Theory and Applications,(2009), Fourth Edition,
3. Churchman, C.W, Ackoff, R.L and Arnoff, E.L. (1957): Introduction to Operations Research. John Wiley.
4. S. D. Sharma, R. K. Malhotra, Operations Management,
5. Shenoy, G.V., Srivastava, U.K and Sharma, S.C: Operations Research for management. New Age Publications.
6. Kalavathy S - Operations Research (Vikas Publishers)
7. Mustafi, C.K. Operations Research methods and practice. New Age. Pub.
8. Mital, K.V. Optimization method. New Age Pub.
9. Narag. A. S. Linear Programming and Decision making. Sultan Chand & Co.
10. Kapoor, V. K. Operations Research. Sultan Chand & Co.
11. N. D. Vohra: Quantitative Techniques in Management (Tata McGraw Hill)
12. John Verzani (2005): Using R for Introductory Statistics, CHAPMAN & HALL/CRC

Pedagogy

1. The course is taught using traditional chalk and talk method using problem solving through examples and exercises.
2. Students are encouraged to use resources available on open sources.

MODEL BLUEPRINT		
Code number:		STDE – 6221
Title of the paper:		Operations Research
Unit number	Number of hrs	Total marks
1	17	35
2	7	14
3	13	27
4	5	10
Total	42	86
Maximum marks for the paper (Excluding bonus questions)		60

STOE – 1:

Statistical Methods

Course Objectives:

1. This is an open elective course for other than statistics students.
2. The students will learn the elements of descriptive statistics, probability, statistical methods such as tests of hypotheses, correlation and regression.

Course Pre-requisite: II PUC or equivalents with Mathematics

Course Outcomes

Upon the completion of this course students should be able to

- CO1: Acquire knowledge of statistical methods.
- CO2: Identify types of data and visualization, analysis and interpretation.
- CO3: Know about elementary probability and probability models.
- CO4: Employ suitable test procedures for given data set.

Pedagogy

The course is taught using traditional chalk and talk method using problem solving through examples and exercises. Students are encouraged to use resources available on open sources.

Unit 1: Introduction

10 Hours

Definition and scope of Statistics. Data: quantitative and qualitative, attributes, variables, scales of measurement - nominal, ordinal, interval and ratio. Presentation: tabular and graphic, including histogram and ogives. Concepts of statistical population and sample. Sampling from finite population - Simple random sampling, Stratified and systematic random sampling procedures (definitions and methods only). Concepts of sampling and non-sampling errors.

Unit 2: Univariate and Bivariate Data Analysis

10 Hours

Measures of Central Tendency: mathematical and positional. Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation, moments, skewness and kurtosis. Bivariate data, scatter diagram, Correlation, Karl-Pearson's correlation coefficient, Rank correlation. Simple linear regression, principle of least squares and fitting of polynomials and exponential curves.

Unit 3: Probability and Distributions

12 Hours

Probability: Random experiment, trial, and sample space, events-mutually exclusive and exhaustive events. Classical, statistical and axiomatic definitions of probability, addition and multiplication theorems, Bayes theorem (only statements). Discrete and continuous random variables, probability mass and density functions, distribution functions, expectation of a random variable. Standard univariate distributions: Binomial, Poisson and Normal distributions (Elementary properties and applications only).

Unit 4: Sampling Distributions and Testing of Hypothesis

10 Hours

Distribution of sample mean from a normal population, Chi-square, t and F distributions (No derivations) and their applications.

Statistical Hypothesis - null and alternative hypothesis, simple and composite hypothesis. Type-I and Type-II errors, level of significance, critical region, P-value and its interpretation.

Test for single mean, equality of two means, single variance, and equality of two variances for normal populations.

References

1. Daniel, W. W. (2007) Biostatistics - A Foundation for Analysis in the Health Sciences, Wiley
2. T.W. Anderson and Jeremy D. Finn(1996). The New Statistical Analysis of Data, Springer.
3. Mukhyopadyaya P(1 999). Applied Statistics, New Central book Agency, Calcutta.
4. Ross, S.M.(2014) Introduction to Probability and Statistics For Engineers and Scientists.
5. Cochran, W G (1984): Sampling Techniques, Wiley Eastern, New Delhi.

MODEL BLUEPRINT		
Code number:		STOE – 1
Title of the paper:		Statistical Methods
Unit number	Number of hrs	Total marks
1	10	21
2	10	20
3	12	25
4	10	20
Total	42	86
Maximum marks for the paper (Excluding bonus questions)		60

STOE – 2:

Business Statistics

Course Objectives

1. Provide an introduction to basics of statistics within a financial context.
2. To enable students to use statistical techniques for analysis and interpretation of business data.

Course Pre-requisite: II PUC or equivalents

Course Outcomes

Upon the completion of this course students should be able to:

- CO1: Frame and formulate management decision problems.
- CO2: Understand the basic concepts underlying quantitative analysis.
- CO3: Use sound judgment in the applications of quantitative methods to management decisions.

Pedagogy

The course is taught using traditional chalk and talk method using problem solving through examples and exercises. Students are encouraged to use resources available on open sources.

Unit 1: Statistical Data and Descriptive Statistics

12 Hours

Nature and Classification of data: univariate, bivariate and multivariate data; time-series and cross-sectional data. Measures of Central Tendency: mathematical averages including arithmetic mean, geometric mean and harmonic mean, properties and applications. Positional Averages Mode and Median (and other partition values including quartiles, deciles, and percentiles). Measures of Variation: absolute and relative. Range, quartile deviation, mean deviation, standard deviation, and their coefficients, Properties of standard deviation/variance Skewness: Meaning, Measurement using Karl Pearson and Bowley's measures; Concept of Kurtosis.

Unit 2: Simple Correlation and Regression Analysis

10 Hours

Correlation Analysis: Meaning of Correlation: simple, multiple and partial; linear and non-linear, Correlation and Causation, Scatter diagram, Pearson's co-efficient of correlation; calculation and properties (Proof not required). Correlation and Probable error; Rank Correlation.

Regression Analysis: Principle of least squares and regression lines, Regression equations and estimation; Properties of regression coefficients; Relationship between Correlation and Regression coefficients; Standard Error of Estimate and its use in interpreting the results.

Unit 3: Index Numbers

10 Hours

Definition, Problems involved in the construction of index numbers, methods of constructing index numbers of prices and quantities, simple aggregate and price relatives method, weighted aggregate and weighted average of relatives method, important types of weighted index numbers: Laspeyre's, Paasche's, Bowley's, Marshall-Edgeworth, Fisher's, method of obtaining price and quantity index numbers, tests consistency of index numbers, time reversal test and factor reversal test for index numbers, Uses and limitations of index numbers. Consumer price index number: Problems involved in the construction of cost-of-living index number, advantages and disadvantages, Aggregative expenditure method and Family budget method for the construction of consumer price index numbers. Applications of Cost-of-Living Index numbers. Definition and measurement of Inflation rate - CPI and GNP Deflator.

Unit 4: Time Series Analysis**10 Hours**

Introduction, definition and components of Time series, illustrations, Additive, Multiplicative and mixed models, analysis of time series, methods of studying time series: Secular trend, method of moving averages, least squares method - linear, quadratic, exponential trend fittings to the data. Seasonal variation - definition, illustrations, measurements, simple average method, ratio to moving average method, ratio of trend method, link relatives method, Cyclical variation- definition, distinction from seasonal variation, Irregular variation- definition, illustrations.

References

1. Levin, Richard, David S. Rubin, Sanjay Rastogi, and HM Siddiqui. Statistics for Management. 7th ed., Pearson Education.
2. David M. Levine, Mark L. Berenson, Timothy C. Krehbiel, P. K. Viswanathan, Business Statistics: A First Course, Pearson Education.
3. Siegel Andrew F. Practical Business Statistics. McGraw Hill Education.
4. Gupta, S.P., and Archana Agarwal. Business Statistics, Sultan Chand and Sons, New Delhi.
5. Vohra N. D., Business Statistics, McGraw Hill Education.
6. Murray R Spiegel, Larry J. Stephens, Narinder Kumar. Statistics (Schaum's Outline Series), Mc-Graw Hill Education.
7. Gupta, S.C. Fundamentals of Statistics. Himalaya Publishing House.
8. Anderson, Sweeney, and Williams, Statistics for Students of Economics and Business, Cengage Learning

MODEL BLUEPRINT		
Code number:		STOE – 2
Title of the paper:		Business Statistics
Unit number	Number of hrs	Total marks
1	12	25
2	10	20
3	10	21
4	10	20
Total	42	86
Maximum marks for the paper (Excluding bonus questions)		60

STOE – 3: Applied Statistics

Course Objectives

1. To enable the students to use statistical tools in finance, industries, population studies and health sciences.
2. To acquire knowledge about sampling methods for surveys.

Course Pre-requisite: II PUC or equivalents with Mathematics

Course Outcomes (CO)

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

- CO1: Understand the Price and Quantity Index numbers and their different measures, understand the applicability of cost-of-living Index number.
- CO2: Know the components and Need for Time series, understand the different methods of studying trend and Seasonal Index.
- CO3: Study the concept of vital statistics, sources of data, different measures of Fertility and Mortality, Understand the Growth rates- GRR and NRR and their interpretations.
- CO4: Know the concept of Population, Sample, Sampling unit, sampling design, sampling frame, sampling scheme, need for sampling, apply the different sampling methods for designing and selecting a sample from a population, explain sampling and non-sampling errors.
- CO5: Describe the philosophy of statistical quality control tools as well as their usefulness in industry and hence develop quality control tools in a given situation.

Pedagogy

The course is taught using traditional chalk and talk method using problem solving through examples and exercises. Students are encouraged to use resources available on open sources.

Unit 1: Economic Statistics

12 Hours

Index numbers: Definition, Criteria for a good index number, different types of index numbers. Construction of index numbers of prices and quantities, consumer price index number. Uses and limitations of index numbers. Consumer price index number: construction of consumer price index numbers. Applications of consumer price index numbers

Time Series Analysis: Components of time series, Decomposition of time series- Additive and multiplicative model with their merits and demerits, Illustrations of time series. Measurement of trend by method of free-hand curve, method of semi-averages and method of least squares (linear). Measurement of seasonal variations by method of ratio to trend.

Unit 2: Vital Statistics

10 Hours

Sources of demographic data, errors in data.

Measurement of mortality: crude death rate, specific death rates, and standardized death rates, infant mortality rate, maternal mortality rate, neo natal mortality rates, merits and demerits and comparisons of various mortality rates.

Measurement of Fertility and Reproduction: Fecundity, fertility, measurement of fertility, crude birth rate, general fertility rate, age specific fertility rate and total fertility rates, merits and demerits of each measure of fertility, comparative study of these measures of fertility, Growth rates: Gross reproduction rate and Net reproduction rates.

Unit 3: Sampling Theory**10 Hours**

Population and Sample. Need for sampling, Complete Enumeration versus Sample Surveys, Merits and Demerits, non – Probability and Probability Sampling, Need and illustrations. Use of random numbers, Principal steps in sample survey. Requisites of a good questionnaire. Pilot surveys, Sampling and non – sampling errors, Description of SRS, simple random sampling with and without replacement procedures, Merits and demerits of Simple random sampling.

Need for stratification, stratifying factors, Merits and demerits of stratified random sampling. Systematic random sampling procedure of obtaining sample, Merits and demerits of systematic random sampling.

Unit 4: Statistical Quality Control**10 Hours**

Concept of quality and its management

Causes of variations in quality: chance and assignable. General theory of control charts,

Control charts for variables: X- bar and R-charts. Control charts for attributes: p and c-charts.

Acceptance Sampling Plans (Product control): Basic terminologies: AQL, LTPD, AOQ, AOQL, ASN, OC curve, producer's risk, and consumer's risk. Single sampling plan, double sampling plan.

References

1. J. Medhi (1992) Statistical Methods. New Age International (P) Ltd. New Delhi.
2. M.N. Das (1993) Statistical Methods and Concepts. Wiley Eastern Ltd.
3. Irwin Miller, John E Freund and Richard A Johnson (1992) Probability and Statistics for Engineers. Prentice Hall of India New Delhi.
4. D.C. Montgomery (1996) Introduction to Statistical Quality Control.
5. Cochran, W G. (1984) Sampling Techniques, Wiley Eastern, New Delhi.
6. Mukhopadhyaya P (1998) Theory and Methods of Survey Sampling. Prentice Hall of India.
7. Mukhopadhyay P. (2011): Applied Statistics, 2nd ed. Revised reprint, Books and Allied
8. Kendall M.G. (1976): Time Series, Charles Griffin.
9. Chatfield C. (1980): The Analysis of Time Series –An Introduction, Chapman & Hall.

MODEL BLUEPRINT		
Code number:		STOE – 3
Title of the paper:		Applied Statistics
Unit number	Number of hrs	Total marks
1	12	25
2	10	20
3	10	21
4	10	20
Total	42	86
Maximum marks for the paper (Excluding bonus questions)		60

STOE – 4: Biostatistics

Course Objectives

1. To enable the students to identify the variables of biological studies and explore the tools of classification and presentation.
2. To study the probability notion, models and their applications in the study of biological phenomenon.
3. To acquire knowledge on sampling distribution and testing of hypotheses.

Course Pre-requisite: II PUC or equivalents with Mathematics

Course Outcomes

After studying the course, the student will be able to apply statistical tools and techniques in data analysis of biological sciences.

Pedagogy

The course is taught using traditional chalk and talk method using problem solving through examples and exercises. Students are encouraged to use resources available on open sources.

Unit 1: Introduction to Bio-Statistics

10 hours

Definition and scope of Statistics. Scales of Measurement: nominal, ordinal, interval and ratio. Collection, classification and tabulation of data, construction of frequency table for grouped and ungrouped data, graphical representation of data by Histogram, Polygon, Ogive curves and Pie diagram.

Unit 2: Descriptive Statistics

12 hours

Measures of Central Tendency: Arithmetic mean, Median and Mode- definition, properties, merits and limitations. Measures of Dispersion: Range, Standard deviation and Coefficient of Variation. Correlation and Regression Analysis: Relation between two variables, definition of correlation, types of correlation, Scatter diagram, Karl-Pearson's coefficient of linear correlation and its properties, Spearman's Rank Correlation coefficient. Regression- Simple linear regression, fitting of regression equations by method of Least Squares, linear regression coefficients and their properties.

Unit 3: Probability and Distributions

10 Hours

Probability: Random experiment, sample space, events-mutually exclusive and exhaustive events. Classical, statistical and axiomatic definitions of probability, addition and multiplication theorems, Bayes' theorem (only statements).

Discrete and continuous random variables, probability mass and density functions, distribution functions, expectation of a random variable.

Standard univariate distributions: Binomial, Poisson and Normal distributions (Elementary properties and applications only).

Unit 4: Sampling Distributions and Statistical Inference

10 Hours

Concepts of random sample and statistic, distribution of sample mean from a normal population, Chi-square, t and F distributions (No derivations) and their applications. Estimation of population mean, population standard deviation and population proportion from the sample counter parts.

Statistical Hypothesis – null and alternative hypothesis, simple and composite hypothesis. Type I and Type II

errors, size, level of significance, power test, critical region, P-value and its interpretation. Test for single mean, equality of two means, single variance, equality of two variances for normal Populations, Test for proportions.

References

1. Dutta, N. K. (2004), Fundamentals of Biostatistics, Kanishka Publishers.
2. Gurumani N. (2005), An Introduction to Biostatistics, MJP Publishers.
3. Daniel, W. W. (2007), Biostatistics - A Foundation for Analysis in the Health Sciences, Wiley
4. Rao, K. V. (2007), Biostatistics - A Manual of Statistical Methods for use in Health Nutrition and Anthropology
5. Pagano, M. and Gauvreau, K. (2007), Principles of Biostatistics.
6. Rosner Bernard (2010), Fundamentals of Biostatistics, 6th Edition, Duxbury.

MODEL BLUEPRINT		
Code number:		STOE – 4
Title of the paper:		Bio Statistics
Unit number	Number of hrs	Total marks
1	10	20
2	12	25
3	10	21
4	10	20
Total	42	86
Maximum marks for the paper (Excluding bonus questions)		60

STOE – 5:

Statistical Methods for Population Studies

Course Objectives

1. To enable the students to use statistical tools in population studies.
2. To acquire knowledge about application of statistics by government.

Course Pre-requisite: II PUC or equivalents

Course Outcomes

After studying the course, the student will be able to apply statistical tools and techniques in population studies and related sectors.

Pedagogy

The course is taught using traditional chalk and talk method using problem solving through examples and exercises. Students are encouraged to use resources available on open sources.

Unit 1: Vital Statistics

14 Hours

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.

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).

Measurement of Population Growth Crude rates of natural increase, Pearl's Vital Index, Gross Reproduction Rate (GRR), and Net Reproduction Rate (NRR).

Unit 2: Lifetables

8 Hours

Life (Mortality) Tables: Assumption, descriptions of Complete and Abridged 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.

Unit 3: Official Statistics

8 Hours

An outline of the present official statistical system in India, Methods of collection of official statistics, their reliability, and limitations. Role of Ministry of Statistics & Program Implementation (MoSPI), Central Statistical Office (CSO), National Sample Survey Office (NSSO), Registered General Office, and National Statistical Commission. The government of India's Principal publications contains data on the topics such as Agriculture, price, population, industry, finance, and employment.

Unit 4: Index number

12 Hours

Definition, Problems involved in the construction of index numbers, methods of constructing index numbers of prices and quantities, simple aggregate and price relatives method, weighted aggregate and weighted average of relatives method, important types of weighted index numbers: Laspeyre's, Paasche's, Bowley's, Marshall-Edgeworth, Fisher's, method of obtaining price and quantity index numbers, tests consistency of index numbers,

time reversal test and factor reversal test for index numbers, Uses and limitations of index numbers. Consumer price index number: Problems involved in the construction of cost-of-living index number, advantages and disadvantages, Aggregative expenditure method and Family budget method for the construction of consumer price index numbers. Applications of Cost-of-Living Index numbers. Definition and measurement of Inflation rate - CPI and GNP Deflator.

References

1. Mukhopadhyay, P. (1999): Applied Statistics, Books and Allied (P) Ltd.
2. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th Edition, World Press.
3. Biswas, S. (1988): Stochastic Processes in Demography & Application, Wiley Eastern Ltd.
4. Keyfitz, N and Caswell. H (2005): Applied Mathematical Demography (3rd edition), Springer.
5. Chattopadhyay, A.K. and Saha, A.K. (2012): Demography: Techniques and Analysis, Viva Books.
6. Ramakuar, R. and Gopal, Y.S. (1986): Technical Demography. Wiley Eastern Ltd.
7. Spiegelman M. (1980): Introduction to Demography, Harvard University Press.
8. Mishra B.D. (1980): An Introduction to the Study of Population, South Asian Pub.
9. Guide to current Indian Official Statistics, Central Statistical Office, GOI, and New Delhi. <http://mospi.nic.in/>

MODEL BLUEPRINT		
Code number:		STOE – 5
Title of the paper:		Statistical Methods for Population Studies
Unit number	Number of hrs	Total marks
1	14	29
2	8	16
3	8	16
4	12	25
Total	42	86
Maximum marks for the paper (Excluding bonus questions)		60

STOE – 6:

Introduction to R Software

Course Objectives

1. This is an open elective course for other than statistics students.
2. The students will learn the about the statistical analysis using software R.

Course Pre-requisite: II PUC or equivalents with statistics and or mathematics

Course Outcomes

After studying the course, the student will be able to apply statistical software R in various statistical analysis.

Pedagogy

The course is taught using PowerPoint or R Software using problem solving through examples and exercises. Students are encouraged to use resources available on open sources.

Unit 1: Introduction to R

10 Hours

Introduction to R: Installation, command-line environment, an overview of capabilities, brief mention of open-source philosophy.

R as a calculator: The four basic arithmetic operations. Use of parentheses nesting up to arbitrary level. The power operation. Evaluation of simple expressions. Quotient and remainder operations for integers.

Unit 2: Numbers, vectors, Graph

10 Hours

The different types of numbers in R: Division by zero leading to Infor -Inf. NaN. NA. No need to go into details. Variables. Creating a vector using `c()`, `seq()` and colon operator. How functions map over vectors.

Functions to summarize a vector: `sum`, `mean`, `sd`, `median` etc. Extracting a subset from the vector (by index, by property).

R as a graphing calculator: Introduction to plotting. `plot()`, `lines()`, `abline()`. (No details about the graphics parameters except color and line width.) Barplot, Pie chart and Histogram. Box plot. Scatter plot and simple linear regression using `lm(y~x)`.

Unit 3: Matrix and data frames

8 Hours

Matrix operations in R: Creation. Basic operations. Extracting submatrices.

Loading data from a file: `read.table()` and `read.csv()`. (Mention of `head=TRUE` and `head=FALSE`). Data frames. (Mention that these are like matrices, except those different columns may be of different types.)

Unit 4: Case studies

14 Hours

Descriptive data analysis, Simple analysis and create and manage statistical analysis projects. Generate automated reports giving detailed descriptive statistics, correlation and simple linear regression.

References

1. Gardener, M (2012) Beginning R: The Statistical Programming Language, Wiley Publications.
2. Braun W J, Murdoch D J (2007): A First Course in Statistical Programming with R. Cambridge University Press. New York
3. A simple introduction to R by Arnab Chakraborty (freely available at <http://www.isical.ac.in/~arnabc/>)
4. R for beginners by Emmanuel Paradis (freely available at https://cran.r-project.org/doc/contrib/Paradisrdebuts_en.pdf)

MODEL BLUEPRINT		
Code number:		STOE – 6
Title of the paper:		Introduction to R Software
Unit number	Number of hrs	Total marks
1	10	14
2	10	14
3	8	12
4	14	20
Total	42	60

Note: Pattern of Semester end examination is multiple Choice Questions

STOE – 7:

An introductory course in Operations Research

Course Objectives

1. To enable the students to use concepts of Operations research in their respective fields.
2. To acquire knowledge about mathematical formulation of real-life concerns

Course Pre-requisite: II PUC or equivalents with mathematics. Students who have taken open elective from dept of statistics earlier shall be given priority

Course Outcomes

After studying the course, the student will be able to apply concepts of operations research in their respective fields. There would be a change in paradigm in approach to their field of interest

Pedagogy

The course is taught using traditional chalk and talk method using problem solving through examples and exercises. Students are encouraged to use resources available on open sources.

Unit-1: Introduction to O.R and L.P.P:

12 Hours

Definition and scope of operations research (OR). Modeling and solution. Linear programming problem (L.P.P) Definition, Standard, and canonical forms. Formulation of LPP. Basic solutions, Degenerate, and non-degenerate solutions. Fundamental theorem of LPP. The graphical solution. Concepts of slack, surplus, and artificial variables, and Simplex algorithm for solving an LPP with 3 variables only.

Unit-2: Transportation problem and Assignment problem:

12 Hours

Transportation problem: Mathematical formulation, finding an initial basic feasible solution by north west corner rule, least cost entry method, and Vogel's approximation method.

Assignment problem: Mathematical formulation and Hungarian algorithm,

Unit-3: Game theory:

10 Hours

Game theory-Basic concepts. Two-person zero-sum game, Pure and mixed strategies. Maximin–Minimax principle, Games with a saddle point. Games without Saddle point - mixed strategies, Determination of optimum solution for (2x2) game. Solution by graphical method for (2x4) and (4x2) games.

Unit-4: Network analysis and Queuing theory:

08 Hours

Basic element of network, Drawing of project network, Project planning with CPM and PERT.

Basic elements, description of a queuing system, and measures of effectiveness. Elements of Queuing systems queuing system. Description of M/M/C queuing system.

References

1. Kanthiswarop, Manmohan and P.K. Gupta (2003) Operations Research. Sultan Chand & Co.
2. S D Sharma, Operations Research: Theory and Applications, (2009), Fourth Edition,
3. Churchman, C.W, Ackoff, R.L and Arnoff, E.L. (1957): Introduction to Operations Research. John Wiley.
4. S. D. Sharma, R. K. Malhotra, Operations Management,
5. Shenoy, G.V., Srivastava, U.K and Sharma, S.C: Operations Research for management. New Age Publications.
6. Kalavathy S - Operations Research (Vikas Publishers)
7. Mustafi, C.K. Operations Research methods and practice. New Age. Pub.
8. Mital, K.V. Optimization method. New Age Pub.

MODEL BLUEPRINT		
Code number:		STOE – 7
Title of the paper:		An introductory course in Operations Research
Unit number	Number of hrs	Total marks
1	12	25
2	12	25
3	10	20
4	8	16
Total	42	86
Maximum marks for the paper (Excluding bonus questions)		60
