SHIVAJI UNIVERSITY, KOLHAPUR
SYLLABUS (SEMESTER PATTERN)
B.A. III: STATISTICS
(With Effect from June 2016)

1. TITLE : B.A. Part III (Statistics)

   Under Faculty of Science.

2. YEAR OF : Syllabus (Semester Pattern) will be

   IMEPLENTATION **Implemented from June 2016 & onwards.**

3. DURATION : B.A. III-Two Semester (One year)

4. PATTERN OF EXAMINATION : Semester

   A) Theory Examination : At the end of each Semester as per Shivaji University Rule.
   B) Practical Examination : In Semester VI, an External Practical Examination will be conducted. There will be two Practical papers of 50 marks each for two days of four hours duration.

5. MEDIUM OF INSTRUCTION : English

6. STRUCTURE OF COURSE : B.A. III
   Two Semesters
   Eight Theory Papers and Two Practical Papers.

Sr. No	Semester	Paper No.	Name of Paper	Distribution of Marks		
				Theory	Practical	Total
1	V	VII	Continuous Probability Distributions - II	**50**	---	**50**
2	V	VIII	Applied Statistics - I	**50**	---	**50**
3	V	IX	Statistical Methods	**50**	---	**50**
4	V	X	Operations Research	**50**	---	**50**
5	V	XI	Practical Paper - I	---	**50**	**50**

Sr. No	Semester	Paper No.	Name of Paper	Distribution of Marks		
				Theory	Practical	Total
1	VI	XII	Designs of Experiments	**50**	---	**50**
2	VI	XIII	Statistical Inference	**50**	---	**50**
3	VI	XIV	Sampling Methods	**50**	---	**50**
4	VI	XV	Applied Statistics - II	**50**	---	**50**
5	VI	XVI	Practical Paper - II	---	**50**	**50**

7. SCHEME OF TEACHING

Sr. No	Semester	Paper No.	Name of Paper	Distribution of Work Load		
				Theory (lectures per Week)	Practical per Batch per Week	Total
1	V	VII	Continuous Probability Distributions - II	**4**	---	**4**
2	V	VIII	Applied Statistics - I	**4**	---	**4**
3	V	IX	Statistical Methods	**4**	---	**4**
4	V	X	Operations Research	**4**	---	**4**
5	V	XI	Practical Paper - I	---	**16**	**16**
6	VI	XII	Designs of Experiments	**4**	---	**4**
7	VI	XIII	Statistical Inference	**4**	---	**4**
8	VI	XIV	Sampling Methods	**4**	---	**4**
9	VI	XV	Applied Statistics - II	**4**	---	**4**
10	VI	XVI	Practical Paper - II	---	**16**	**16**

- Weekly there will be practical of four hours for four days.

8. SCHEME OF EXAMINATION:

- The examination shall be at the end of each semester.
- All papers shall carry 50 marks for Theory Papers.
- The evaluation of the performance of the students in theory shall be on the basis of semester examination as mentioned above.
- Question paper will be set in the view of the entire syllabus preferably covering each unit of the syllabus. In theory examination weightage to numerical problems should not exceed 40%.
- Use of calculators is allowed for both theory and practical examinations.

- **Nature of question paper (Theory):**

o There will be Ten objective type question of one mark each consisting of 4 multiple choices.
o Short answer type questions having 20 marks (Four out of Six of five marks each).
o Long answer questions having 20 marks (Two out of Three of ten marks each).

- **Nature of question paper (Practical):**

o There will be two practical papers of four hours duration at the end of Semester VI.
o There will be four questions of 20 marks each. Student has to attempt any two questions.
o Five marks are reserved for journal and Five marks are reserved for Oral.
o A student must complete all practicals and he/she has to produce journal along with completion certificate at the time of practical examination. Duration of practical examination will be **Four hours**.

- The evaluation of the performance of the students in practical shall be done by the university by appointing Two external examiner at the time of University Practical Examination.

- **Standard of Passing:**
  In order to pass student shall have to secure 35% marks in each of theory and practical examination separately.

SHIVAJI UNIVERSITY, KOLHAPUR
SYLLABUS FOR B.A. III: STATISTICS
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SEMESTER – V: PAPER – VII
Continuous Probability Distributions-II

Unit-1: Gamma and Beta Distributions: (13)

1.1: **Gamma distribution**: Gamma distribution with scale parameter θ and shape parameter n, special case $\theta = 1$, $n = 1$, m. g. f., c. g. f., mean, mode, variance, moments, Cumulants, β_1, β_2, γ_1 and γ_2 coefficients, additive property, distribution of sum of i.i.d. exponential variates.

1.2: **Beta distribution of first kind**: Beta distribution of first kind with parameters m & n. mean, mode, variance, symmetric when m = n, Uniform distribution as a particular case when m = n = 1, distribution of (1-X).

1.3: **Beta distribution of second kind**: Beta distribution of second kind with parameters m & n. mean, mode, variance, relation between beta distribution of first kind and second kind, distribution of X+Y, X/Y and X/(X+Y) where X and Y are independent gamma variate.

Unit-2: Normal distribution: (12)

Normal distribution with parameters μ & σ^2, Definition of standard normal distribution, properties of normal curve, m. g. f., c. g. f., mean, variance, median, mode, mean deviation, moments, Cumulants, measures of skewness & kurtosis, distribution of linear combination of variates. Distribution of X^2 if $X \sim N(0, 1)$.

Unit-3: Lognormal Distribution and Weibull Distribution: (08)

3.1: **Lognormal Distribution:** P. d. f. with parameters(μ, σ^2), Nature of the probability curve, mean, variance, median, mode, moments, β_1, β_2, γ_1 and γ_2 coefficients, Relation with N(μ, σ^2), examples and problems.

3.2: **Weibull Distribution:** P. d. f. with parameters (α, β), distribution function, mean and variance, relation with gamma and exponential distribution, examples and problems

Unit-4: Exact Sampling Distributions (t, F and χ^2): (12)

4.1: **Chi-Square distribution**: Definition of chi-square, derivation of p. d. f. of chi square distribution with n degrees of freedom using m. g. f.. c. g. f., mean, variance, moments, Cumulants, mode, skewness and kurtosis, additive property.

4.2: **Student's t- distribution**: Definition of student's t variate. Derivation of p. d. f., mean, mode, variance, moments, β_1, β_2, γ_1 and γ_2 coefficients.

4.3: **Snedecor's F distribution**: Definition of F variate, derivation of p. d. f., mean, variance and mode. Distribution of 1/F. Inter relation between t, F and χ^2 (Without Proof).

References

1. Hogg R.V. and Criag A.T.: Introduction to Mathematical Statistics (Third edition), Macmillan Publishing, New York.
2. Gupta S. C. & Kapoor V.K.: Fundamentals of Mathematical Statistics. Sultan Chand & sons, New Delhi.

3. Gupta S. C. & Kapoor V.K.: Applied Statistics. Sultan Chand & sons, New Delhi.
4. Goon, A.M., Gupta M.K. and Dasgupta B: Fundamentals of Statistics Vol. I and Vol. II World Press, Calcutta.
5. Sanjay Arora and Bansi Lal : New Mathematical Statistics (First Edition), Satya Prakashan, 16/17698, New Market, New Delhi, 5 (1989).
6. Feller. W. : An Introduction of Probability Theory and its Applications, Wiley Eastern Ltd.. Mumbai.
7. Bhat B. R.: Modern Probability Theory. New Age International.

SEMESTER – V: PAPER – VIII
Applied Statistics – I

Unit 1: Time Series: **(08)**

1.1: Meaning and need of time series analysis, components of Time series (i) Secular trend (ii) Seasonal Variation (iii) Cyclical Variation (iv) Irregular Variation, Additive and Multiplicative model, utility of time series.

1.2: Measurement of trend: (i) Moving average method (ii) Progressive average method (iii) Least square method (iv) Measurement of seasonal indices by simple average method.

Unit 2: Statistical Quality Control: **(12)**

2.1: Meaning and purpose of S.Q.C., Process control, Product control, chance causes, assignable causes, Shewart's control chart- construction & working, lack of control situation.
2.2: Control chart for variables - control chart for mean, control chart for range, construction and working of mean & range charts for unknown standards.
2.3: Control chart for Attributes – Defects, defectives, fraction defective, control chart for number of defectives (np-chart) for fixed sample size and unknown standards, construction and working of chart. Control charts for number of defects (C-chart), for unknown standards, construction and working of C-chart.

Unit-3: Index Numbers: **(13)**

3.1: Meaning and utility of index numbers, problems in construction of index numbers.
3.2: Types of index numbers: price, quantity and value.
3.3: Unweighted and weighted index numbers using (i)aggregate method,(ii) average of price or quantity relative method (A.M. or G.M. is to be used as an average)
3.4: Index numbers using; Laspeyre's, Paasche's and Fisher's formula.
3.5: Tests of index numbers: unit test, time reversal test and factor reversal tests.
3.6: Cost of living index number: definition, construction by using (i) Family Budget and (ii) Aggregate expenditure method.
3.7: Shifting of base and purchasing power of money.

Unit-4: Demography **(12)**

4.1: Introduction and need of vital statistics

4.2: Mortality rates: Crude death rate (CDR), Specific Death Rate (SDR), Standardized Death Rate (STDR).

4.3: Fertility Rates: Crude Birth Rate (CBR), Age Specific Fertility Rate (ASFR), General Fertility Rate (GFR), Total Fertility Rate (TFR).

4.4: Reproduction Rate: Gross Reproduction rate (GRR), Net Reproduction Rate (NRR).

References

1. Goon, A.M., Gupta M.K. and Dasgupta B: Fundamentals of Statistics Vol. I and Vol. II World Press, Calcutta.
2. Gupta S. C. & Kapoor V.K.: Applied Statistics. Sultan Chand & sons, New Delhi.
3. Gupta S.P: Statistical Methods, Sultan Chand and Sons, New Delhi.
4. Kanti Swarup, Gupta P.K. and Man Mohan : Operations Research, Twelfth edition, Sultan Chand & sons
5. Sharma J. K.: Mathematical Models in Operations Research, Tata McGraw Hill Publishing Companies
6. Sharma S. D.: Operations Research, Eighth edition, Kedarnath Ramnath & Co.
7. Snedecor G.W. and Cochoran W. G. Statistical Methods.Lowa State University Press.
8. Srivastav D.S: A Text book of Demography. Speigelman: Demography.
9. Taha H. A.: Operation research – An Introduction, Eighth edition, Prentice Hall of India, New Delhi
10. Waikar and Lev: Elementary Statistical Methods.

SEMESTER – V: PAPER – IX
Statistical Methods

Unit 1: Tests of Hypothesis **(12)**

Notion of Population and Sample Definition of Population, Sample, Parameter, Statistic, Sampling distribution of Statistic (statement only), Standard error of statistic, hypothesis, Simple and composite hypothesis, Null and alternative hypothesis, test statistic, critical region, idea of one & two tailed tests, type I and type II errors, level of significance, p-value, power of a test.

Unit 2: Large sample tests: **(12)**

Statement of Central Limit Theorem (CLT) for i.i.d. r.v.s., concept of constructing a test statistic and identification of its probability distribution.

(*a*) Tests for means: i) $H_0: \mu = \mu_0$ ii) $H_0: \mu_1 = \mu_2$.

(*b*) Tests for proportion: i) $H_0: P = P_0$ ii) $H_0: P_1 = P_2$

Unit 3: Small sample tests: **(13)**

3.1: Statement about independence of sample mean and sample variance.

3.2: t-tests for means: i) H_0: $\mu = \mu_0$ (σ unknown), ii) H_0: $\mu_1 = \mu_2$ ($\sigma_1=\sigma_2$ unknown) unpaired t test. iii) H_0: $\mu_1 = \mu_2$ (paired t test).

3.3: Chi-square tests: (i) test for population variance, (ii) test for goodness of fit,

(iii) tests for independence of attributes

(a) m × n contingency table,

(b) 2 ×2 contingency table, Yates's correction for continuity.

3.4: F-tests: test for equality of population variance.

Unit 4: Non parametric tests: **(08)**

4.1: Concept of Non parametric test.

4.2: Run Test: Single sample

4.3: Mann Whitney U – Test for single and double sample.

4.4: Signed Rank Test.

References

1. Duncan A.J. : Quality control and Industrial Statistics. Tataporewala & Sons Co. Mumbai.
2. Gupta S. C. & Kapoor V.K.: Fundamentals of Mathematical Statistics. Sultan Chand & sons, New Delhi.
3. Gupta S. C. & Kapoor V.K.: Applied Statistics. Sultan Chand & sons, New Delhi.
4. Gupta S.C. : Fundamentals of Statistics. Himalaya Publishing House, Mumbai
5. Gupta S. D. : Statistical Methods. Sultan Chand & sons, New Delhi.
6. Goon A.M., Gupta A.K.: Fundamentals of Statistics (Vol. II) and Dasgupta B. World Press, Calcutta.
7. Grant E. L. : Statistical Quality Control.
8. Gupta S.P. : Statistical Method.
9. Hogg R.V. and Criag A.T.: Introduction to Mathematical Statistics (Third edition), Macmillan Publishing, New York.
10. Kapoor J.N. & Saexna H.C.: Mathematical Statistics. Sultan Chand & sons, New Delhi.
11. Kangji K. : 100 Statistical Tests.
12. Kulkarni M.B., Gore A.P. & Ghatpande S.B.: Common Statistical Tests. Satyajeet Prakashan, Pune.
13. Mayer P.L.: Introductory probability & Statistical Applications. Addison Weseley Publication Co., London.
14. Mood A.M., Graybill F.A.: Introduction to theory of Statistics. Boes D.C. Tata, McGraw Hill, New Delhi. (Third Edition)
15. Montgomery D.C.: Introduction to Statistical Quality Control.
16. Rohatgi V.K. : Introduction to Probability theory & Mathematical Statistics. Wiley Eastern Ltd.
17. Walpole R.E. & Mayer R.H.: Probability & Statistics. (Chapter 4, 5, 6, 8, 10) MacMillan Publishing Co. Inc, New York.

SEMESTER – V: PAPER – X
Operations Research

Unit-1: Linear programming **(15)**

1.1: Basic concepts

Statement of the Linear Programming Problem (LPP), formulation of problem as.L.P. P. Definition of (i) a slack variable, (ii) a surplus variable. L.P. problem in (i) Canonical form, (ii) Standard form. Definition of (i) a solution, (ii) a feasible solution, (iii) basic variable and non basic variable, (iv) a basic feasible solution, (v) a degenerate and a non-generate solution, (vi) an optimal solution.

1.2: Solution of L.P.P.

i. Graphical Method**:** Solution space, obtaining an optimal solution, unique and non unique optimal solutions.

ii. Simplex Method:

(a) Initial basic feasible solution (IBFS) is readily available: obtaining an IBFS, criteria for deciding whether obtained solution is optimal, criteria for unbounded solution, , more than one optimal solutions.

(b) IBFS not readily available: introduction of artificial variable, Big-M method, modified objective function, modifications and applications of simplex method to L.P.P., criterion for no solution.

1.3: Duality Theory:

Writing dual of a primal problem, solution of L.P.P. with artificial variable (Solving Dual L.P.P. and writing solution of Primal L.P.P. from final simplex table of dual).

1.4: Examples and problems.

Unit-2: Transportation **(10)**

2.1: Transportation problem

i. Transportation problem (T. P.), statement of T. P., balanced and unbalance T. P.

ii. Methods of obtaining initial basic feasible solution of T.P. (a) North West corner rule (b)Method of matrix minima (least cost method), (c) Vogel's approximation(VAM).

iii. MODI method of obtaining Optimal solution of T. P, uniqueness and non- uniqueness of optimal solutions, degenerate solution.

iv. Examples and problems.

Unit-3: Assignment Problem and Sequencing Problem **(10)**

2.2: Assignment Problem

i. Statement of an assignment problem, balanced and unbalanced assignment problem, relation with T.P, optimal solution of an assignment problem using Hungarian method.

ii. Examples and problems.

2.3: Sequencing Problem

i. Introduction. Statement of problem.

ii. Procedure of processing n jobs on two machines.

iii. Procedure of processing n jobs on three machines and m machines. Computations of elapsed time and idle times.

iv. Examples and problems.

Unit-4: Theory of Game **(10)**

4.1: Introduction
4.2: Two Person Zero-Sum Games
4.3: Minimax and Maximin Principles
4.4: Minimax saddle point Theorems
4.5: Mixed strategies : Games without saddle points
4.6: The Rules of Dominance
4.7: Solution Methods of Games without saddle point: Algebraic method and Matrix Method

References

1. Gass E.: Linear Programming Method and Applications, Narosa Publishing House, New Delhi.
2. Gupta, P. K. and Hira, D. S. : Operations Research, S. Chand and Company Ltd., New Delhi.
3. Kapoor, V. K. : perations Research, Sultan Chand and Sons, New Delhi.
4. Phillips, D. T., Ravindra, A., Solberg, J.: Operations Research Principles and Practice, John Wiley and Sons Inc.
5. Saceini, Yaspan, Friedman : Operations Research Method and Problems, Wiley International Edition.
6. Sharma, J. K. : Mathematical Models in Operations Research, Tau McGraw Hill Publishing Company Ltd., New Delhi.
7. Shrinath L. S.: Linear Programming.
8. Shrinath, L. S. : Linear Programming, Affiliated East-West Press Pvt. Ltd., New Delhi.
9. Taha H. A.: Operation research – An Introduction, Fifth Edition, Prentice Hall of India, New Delhi.

SEMESTER – V: PAPER – XI
Practical Paper- I

1. Application of Normal distribution.
2. Fitting of Normal distribution.
3. Model Sampling from Normal distribution.
4. Model Sampling from Normal distribution (Box Muller Method).
5. Fitting of Lognormal distribution.
6. Model Sampling from Lognormal distribution.
7. Demography -I (Mortality Rates).
8. Demography –II (Fertility rates).
9. Demography –III (Reproduction rates).
10. Index Numbers-I (Computations of index numbers).
11. Index Numbers-II (Tests of adequacy, Shifting of base, cost of living index number).
12. Time Series. (Trend by Progressive averages, Moving average &least square methods).
13. Time Series. (Measurement of Seasonal Indices)

14. Construction of R and $\overline{X}$ charts.
15. Construction of np and C charts.
16. Large sample tests for means.
17. Large sample tests for proportions.
18. Chi-square Test.
19. Tests based on t distribution ($\mu = \mu_0$, $\mu_1 = \mu_2$, paired t test).
20. Tests based on F distribution.
21. Non-Parametric Tests. (Run & Sign Test)
22. Non-Parametric Tests. (Mann Whitney U Test)
23. Linear Programming Problem by Graphical Method.
24. Simplex Method -I
25. Simplex Method -II (Big M Method)
26. Transportation Problem.
27. Assignment Problem.
28. Sequencing Problem.
29. Games Theory-I. (Saddle Point & Rule of Dominance)
30. Games Theory-II. (Graphical & Algebraic Method

SEMESTER – VI: PAPER – XII
Designs of Experiments

Unit – 1: Simple Designs of Experiment -I: **(12)**

1.1. Basic Concepts:

i. Basic terms in design of experiments: Experimental unit, treatment, layout of an experiment.

ii. Basic principles of design of experiments: Replication, randomization and local control.

iii. Choice of size and shape of a plot for uniformity trials, the empirical formula for the variance per unit area of plots.

1.2. Completely Randomized Design:

i. Application of the principles of design of experiments in CRD, layout, model, assumptions and interpretations:
ii. Estimation of parameters, expected values of mean sum of squares, components of variance.
iii. Breakup of total sum of squares into components.
iv. Technique of one way analysis of variance (ANOVA) and its applications to CRD.
v. Testing for equality for treatment effects and its interpretation. F-test for testing H_0, test for equality of two specified treatment effects

Unit – 2: Simple Designs of Experiment -II: **(15)**

2.1 Randomized Block Design (RBD):

i. Application of the principles of design of experiments in RBD, layout, model , assumptions and interpretations:
ii. Estimation of parameters, expected values of mean sum of squares, components of variance.

iii. Breakup of total sum of squares into components.
iv. Technique of two way analysis of variance (ANOVA) and its applications to RBD.
v. Tests and their interpretations , test for equality of two specified treatment effects, comparison of treatment effects using critical difference (C.D.).
vi. Idea of missing plot technique.
vii. Analysis of RBD with single missing observation.

2.2 Latin Square Design (LSD):

i. Application of the principles of design of experiments in LSD, layout, model, assumptions and interpretations
ii. Breakup of total sum of squares into components.
iii. Estimation of parameters, expected values of mean sum of squares, components of variance. preparation of analysis of variance (ANOVA) table.
iv. Tests and their interpretations, test for equality of two specified treatment effects, comparison of treatment effects using critical difference (C.D.).
v. Analysis of LSD with single missing observation.
vi. Identification of real life situations where CRD, RBD and LSD are used.

Unit – 3: Efficiency of Designs: (07)

i. Concept and definition of efficiency of a design.
ii. Efficiency of RBD over CRD.
iii. Efficiency of LSD over CRD and LSD over RBD.

Unit – 4: Factorial Designs: (11)

i. General description of factorial experiments, 2^2 and 2^3 factorial experiments arranged in RBD.
ii. Definitions of main effects and interaction effects in 2^2 and 2^3
iii. Model , assumptions and its interpretation.
iv. Preparation of ANOVA table by Yates's procedure, test for main effects and interaction effects.
v. General idea and purpose of confounding in factorial experiments.
vi. Total confounding (Confounding only one interaction) : ANOVA table, testing main effects and interaction effects.
vii. Partial Confounding (Confounding only one interaction per replicate): ANOVA table, testing main effects and interaction effects.
viii. Construction of layout in total confounding and partial confounding in 2^3 factorial experiment.

References

1. Federer, W.T. : Experimental Design, Oxford and IBH publishing Company, New Delhi.
2. Cochran, W.G. and Cox, G.M. : Experimental Design, John Wiley and Sons, Inc., New York.
3. Montgomery, D.C.: Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
4. Das, M.N. and Giri, N.C. : Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
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9. Gupta, S.C. and Kapoor, V.K. : Fundamentals of Applied Statistics, S. Chand & Sons, New Delhi.
10. C.F. Jeff Wu, Michael Hamada : Experiments, Planning Analysis and Parameter Design Optimization.

SEMESTER – VI: PAPER – XIII
Statistical Inference

Unit - 1: Point Estimation (13)

i. Notion of a parameter, parameter space, general problem of estimation, estimating an unknown parameter by point and interval estimation.

ii. Point estimation: Definition of an estimator (statistic) & its S.E., distinction between estimator and estimate, illustrative examples.

iii. Properties of estimator: Unbiased estimator, biased estimator, positive and negative bias, examples of unbiased and biased estimators. Proofs of the following results regarding the unbiased estimators: (a)Two distinct unbiased estimators of $\varphi(\theta)$ give rise to infinitely many unbiased estimators of $\varphi(\theta)$ (b) If T is unbiased estimator of θ then φ (T) is an unbiased estimator of φ (θ) provided φ (.) is a linear function. Sample variance is a biased estimator of the population variance. Illustration of unbiased estimator for the parameter and parametric function.

iv. Relative efficiency of T_1 with respect to T_2, where T_1 and T_2 are unbiased estimators. Use of mean square error to modify the above definition for biased estimator. Minimum Variance Unbiased Estimator (MVUE) and Uniformly Minimum Variance Unbiased Estimator (UMVUE), uniqueness of UMVUE whenever it exists. Illustrative examples.

v. Consistency : Definition, proof of the following :

i) Sufficient condition for consistency,

ii) If T is consistent for θ and φ (.) is a continuous function then φ (T) is consistent for φ (θ) Illustrative examples.

Unit - 2: Likelihood , Sufficiency and Efficiency (13)

i. Definition of likelihood function as a function of the parameter θ for a random sample from discrete and continuous distributions. Illustrative examples.

ii. Sufficiency: Concept of sufficiency, definition of sufficient statistic through (1) conditional distribution (2) Neyman factorization criterion. Pitman Koopman form and sufficient statistic. Proof of the following properties of sufficient statistic:

(a) If T is sufficient for θ then φ (T) is also sufficient for θ provided φ (.) is a bijective function

(b) If T is sufficient for θ then T is sufficient for φ (θ).

Fisher information function: Definition of information function, amount of information contained in a sample. Statement regarding equality of the information in ($x_1, x_2, \ldots, x_n$) and in a sufficient statistic T, concept of minimal sufficient statistic with illustrations to exponential family.

Illustrative examples.

iii. Concept of Efficiency with examples.

Unit - 3: Cramer Rao Inequality **(09)**

Statement and proof of Cramer Rao inequality. Definition of Minimum Variance Bound Unbiased Estimator (MVBUE) of $\varphi(\theta)$. Proof of the following results:

(i) If MVBUE exists for θ then MVBUE exists for $\varphi(\theta)$, if $\varphi(.)$ is a linear function.

(ii) If T is MVBUE for θ then T is sufficient for θ. Examples and problems.

Unit - 4: Methods of Estimation **(10)**

i. Method of maximum likelihood, derivation of maximum likelihood estimators for parameters of standard distributions. Use of iterative procedure to derive MLE of location parameter μ of Cauchy distribution, invariance property of MLE, relation between MLE and sufficient statistic. Illustrative examples.

ii. Method of moments: Derivation of moment estimators for standard distributions. Illustrations of situations where MLE and moment estimators are distinct and their comparison using mean square error(for uniform distribution). Illustrative examples.

References

1. Kale, B. K.: A first Course on Parametric Inference
2. Rohatgi, V. K.: Statistical Inference
3. Rohatgi, V. K.: An introduction to Probability Theory and Mathematical Statistics
4. Saxena H. C. and Surenderan : Statistical Inference
5. Kendall M. G. and Stuart A.: An advanced Theory of Statistics
6. Lindgren, B. W.: Statistical Theory
7. Lehmann, E. L.: Theory of Point Estimation
8. Rao, C. R.: Linear Statistical Inference
9. Dudewicz C. J. and Mishra S. N. : Modern Mathematical Statistics
10. Fergusson, T. S.: Mathematical statistics.
11. Zacks, S.: Theory of Statistical Inference.
12. Cramer, H.: Mathematical Methods of Statistics.
13. Cassela G. and Berger R. L.: Statistical Inference

SEMESTER – VI: PAPER – XIV
Sampling Methods

Unit – 1 Basic Terminology and Simple Random Sampling (10)

1.1 Basic Terminology

Concept of distinguishable elementary units, sampling units, sampling frame, random sampling and non-random sampling. Advantages of sampling method over census method, objectives of a sample survey, Designing a questionnaire, Characteristics of a good questionnaire, Planning, Execution and analysis of sample survey

1.2 **Simple random sampling**

i. Simple random sampling from finite population of size N with replacement (SRSWR) and without replacement (SRSWOR).

ii. Sample mean $\bar{y}$ as an estimator of population mean, derivation of its expectation, standard error and estimator of standard error.

iii. $N\bar{y}$ as an estimator of population total, derivation of its expectation, standard error and estimator of standard error.

iv. Sampling for dichotomous attributes. Estimation of population proportion: Sample proportion (p) as an estimator of population proportion (P), derivation of its expectation, standard error and estimator of standard error using SRSWOR. Np as an estimator of total number of units in the population possessing the attribute of interest, derivation of its expectation, standard error and estimator of standard error.

Unit – 2 Stratified Sampling : (15)

i. Real life situations where stratification can be used.

ii. Description of stratified sampling method where sample is drawn from individual stratum using SRSWOR method.

iii. a) $\bar{y}$ as an estimator of population mean $\bar{Y}$, derivation of its expectation, standard error and estimator of standard error.

b) N $\bar{y}$ as an estimator of population total, derivation of its expectation, standard error and estimator of standard error.

iv. Problem of allocation: Proportional allocation, Neyman's allocation and optimum allocation, derivation of the expressions for the standard errors of the above estimators when these allocations are used.

v. Comparison amongst SRSWOR, stratification with proportional allocation and stratification with optimum allocation.

Unit-3 Other Sampling Methods **(11)**

3.1 Systematic Sampling

i. Real life situations where systematic sampling is appropriate. Technique of drawing a sample using systematic sampling.
ii. Estimation of population mean and population total, standard error of these estimators.
iii. Comparison of systematic sampling with SRSWOR.
iv. Comparison of systematic sampling with SRSWOR and stratified sampling in the presence of linear trend.
v. Idea of Circular Systematic Sampling.

3.2 Cluster Sampling

i. Real life situations where cluster sampling is appropriate. Technique of drawing a sample using cluster sampling.
ii. Estimation of population mean and population total (with equal size clusters), standard error of these estimators
iii. Systematic sampling as a particular case of cluster sampling.

3.3 Two Stage and Multi Stage Sampling

Idea of two-stage and multistage sampling.

Unit – 4: Sampling Methods using Auxiliary variables **(9)**

4.1 Ratio Method

i. Concept of auxiliary variable and its use in estimation
ii. Situations where Ratio method is appropriate.
iii. Ratio estimators of the population mean and population total and their standard errors (without derivations), estimators of these standard errors.
iv. Relative efficiency of ratio estimators with that of SRSWOR

4.2 Regression Method

i. Situations where Regression method is appropriate.
ii. Regression estimators of the population mean and population total and their standard errors (without derivations), estimators of these standard errors.
iii. Comments regarding bias in estimation
iv. Relative efficiency of regression estimators with that of a) SRSWOR b) Ratio estimator.

References

1. Cochran, W.G: Sampling Techniques, Wiley Eastern Ltd., New Delhi.
2. Des Raj : Sampling Theory.
3. Daroga Singh and Choudhary F.S.; Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd., New Delhi.
4. Murthy, M.N: Sampling Methods, Indian Statistical Institute, Kolkata.
   Mukhopadhay Parimal: Theory and Methods of Survey Sampling, Prentice Hall.

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

SEMESTER – VI: PAPER – XV
Statistical Methods-II

Unit – 1: Queuing Theory (13)

1.1. Introduction, essential features of queuing system, input source, queue configuration, queue discipline, service mechanism.
1.2. Operating characteristics of queuing system, transient- state and steady state, queue length, general relationship among system characteristics.
1.3. Probability distribution in queuing system: Distribution of arrival, distribution of inter arrival time, distribution of departure and distribution of service time. Roles of the Poisson and Exponential distributions.
1.4. Types of queuing models. Notation to represent general queuing model (a / b / c) : (d / e).
1.5. Solution of queuing Model: M / M / 1 : ∞ / FCFS.
1.6. Problems and examples.

Unit – 2: Inventory Management (12)

2.1. Introduction to Inventory Problem
2.2. Deterministic Models:
Single item static EOQ models for:
(i) Constant rate of demand with instantaneous replenishment, with and without shortages.
(ii) Constant rate of demand with uniform rate of replenishment, with and without shortages.
(iii) Constant rate of demand with instantaneous replenishment without shortages, with at most two price breaks.
2.3. Probabilistic models: Single period with
(i) Instantaneous demand (discrete and continuous) without setup cost.
(ii) Uniform demand (discrete and continuous) without set up cost.
2.4. Problems and examples.

Unit – 3: Reliability Theory (10)

3.1. Binary Systems: Block diagrams, definition of binary coherent structure and illustrations. Coherent system with at most three component: (a) Series, (b) Parallel, (c) 2 out of 3. Representation of structure function of a system through that of minimal cuts, minimal paths.
3.2. Reliability of binary System: Reliabilities (h (p)) of above systems, when components are functioning independently and identical reliability p of each component.
3.3. Ageing Properties : Definitions of (a) Hazard rate, (b) hazard function, (c) survival function, Concept of distributions with increasing and decreasing failure rate (IFR, DFR). Relationship between survival function and hazard function; density function and hazard rate. Derivation of (a) Hazard rate of a series system of components having independent life times is summation of component hazard rates. (b) Life time of series system of independent components with independent IFR life times is IFR,
3.4. Examples on exponential and Weibull distribution.

Unit – 4: Critical Path Method (CPM) and Project Evaluation & Review Technique (PERT) (10)

4.1. Definitions: (i) event, (ii) node, (iii) activity, (iv) critical activity, (v) project duration.
4.2. Critical Path Method (CPM): Construction of a network, definitions of (i) earliest event time, (ii) latest event time, (iii) Critical path. Determination of critical path.
4.3. Project Evaluation & Review Technique (PERT) : Construction of network, pessimistic time, optimistic time, most likely time. Determination of critical path, determination of mean, variance and standard deviation of project duration, computations of probability of completing the project in a specified duration.
4.4. Examples and problems.

References

1. Bhat B. R.: Stochastic Models : Analysis and Applications. New Age International.
2. Hoel, Port and Stone: Introduction to Stochastic Processes, Houghton Mifflin.
3. Hoyland A. and Rausand M. : System Reliability Theory – Models and Statistical Methods, John Wiley and Sons.
4. Karlin and Taylor: Stochastic Process.
5. Kanti Swarup, Gupta P.K. and Man Mohan : Operations Research, Twelfth edition, Sultan Chand & sons
6. Lai C. D. and Xie M.,: Stochastic Aging and Dependence for Reliability, Springer.
7. Mann N.R., Schafer R.E., Singapurwalla N.D.: Methods for Statistical Analysis of Reliability and Life Data, First edition, John Wiley & Sons.
8. Medhi J : Stochastic Processes, Second edition. Wiley Eastern Ltd.
9. Sharma S. D.: Operations Research, Eighth edition, Kedarnath Ramnath & Co.
10. Sharma J. K.: Mathematical Models in Operations Research, Tata McGraw Hill Publishing Companies
11. Taha H. A.: Operation research – An Introduction, Eighth edition, Prentice Hall of India, New Delhi
12. Trivedi R. S.: Probability and Statistics with Reliability and Computer Science Application, Prentice – Hall of India Pvt. Ltd., New Delhi.
13. Vora N. D. : Quantitative Techniques in Management, Third edition, McGraw Hill Publishing Companies
14. Zacks S. : Introduction to Reliability Analysis, Probability Models and Statistical Methods, Springer Verlag.

SEMESTER – VI: PAPER – XVI
Practical Paper-II

1. Analysis of CRD and RBD.
2. Analysis of Latin Square Design (LSD).
3. Missing Plot Technique for RBD and LSD with one missing observation.
4. Efficiency of i) RBD over CRD and ii) LSD over CRD and RBD.
5. Analysis of 2^2 and 2^3 Factorial Experiment.
6. Total Confounding.
7. Partial Confounding.
8. Point estimation by method of moments for discrete distributions.

9. Point estimation by method of moment for continuous distributions.
10. Point estimation by method of maximum likelihood (one parameter).
11. Point estimation by method of maximum likelihood (two parameters).
12. Simple Random Sampling for Variables.
13. Simple Random Sampling for Attributes.
14. Stratified Random Sampling – I
15. Stratified Random Sampling – II
16. Systematic Sampling.
17. Cluster Sampling.
18. Ratio Method of Estimation.
19. Regression Method of Estimation.
20. Problems on queuing model M / M / 1 : ∞ / FCFS.
21. Problems on deterministic inventory management.
22. Problems on probabilistic inventory management.
23. Reliability-I: Structure function of a system through structures of minimal paths and minimal cuts.
24. Reliability-II: Reliability of a system through reliabilities of minimal paths and minimal cuts.
25. Reliability-III: Hazard rate of a life-time distribution and its classification into IFR and DFR.
26. Critical Path Method: Construction of project network and obtaining critical paths.
27. Project Evaluation and Review Technique.
28. Inventory Models
29. Queuing Models.