K. J. SOMAIYA COLLEGE OF SCIENCE AND COMMERCE

AUTONOMOUS–Affiliated to University of Mumbai

Re-accredited "A' Grade by NAAC

Vidyanagar, Vidyavihar, Mumbai 400 077

Syllabus for T. Y. B. Sc.

Program: B.Sc.

Course: Statistics

Choice Based Credit System (CBCS)

From the academic year 2020-21

Semester V

Course (Paper)	Course Name	Course Code
I	Probability theory	2OUS5STPT1
II	Probability Distribution	2OUS5STPD2
III	Theory of Estimation	2OUS5STTE3
IV	Demography and Vital Statistics	2OUS5STDV4
V – DSE-1	Regression Analysis	2OUS5STRA5
	Econometrics	2OUS5STEC5
VI - DSE-2	Operation research-II	2OUS5STOR6
	Design of Experiments	2OUS5STDE6
VII-Skill Enhancement Course	Statistical Computing using c-Programming	2OUS5STSCC7

Practical (Semester V)

Paper		Course Code
1	Theory Course I + Theory course II	2OUS5STP1
2	Theory Course III + Theory course IV	2OUS5STP2
3	DSE-1 + DSE-2	2OUS5STP3

Semester VI

Course (Paper)	Course Name	Course Code
I	Survival Analysis	2OUS6STSA1
II	Testing of hypothesis	2OUS6STTH2
III	Stochastic Process	2OUS6STSQ3
IV	Elements of actuarial science	2OUS6STEA4
V – DSE-3	Data Mining	2OUS6STDM5
	Biostatistics	2OUS6STBIO5
VI - DSE-4	Time series analysis	2OUS6STTS6
	Linear Model	2OUS6STLM6
VII-Skill Enhancement Course	Statistical Computing using R	2OUS6STSCR7

Practical (Semester VI)

Paper		Course Code
1	Theory Course I + Theory course II	2OUS6STP1
2	Theory Course III + Theory course IV	2OUS6STP2
3	DSE-3 + Dse-4	2OUS6STP3

Structure of syllabus: T.Y.B.Sc. Statistics
[From 2020-21]

Sem	Course Number	Course Title	Course Code	Credit	Hours	Periods (50 min)	Unit/ Module	Lectures (50 min)	Examination		
									Int. Marks	Ext. Marks	Total Marks
Theory											
V	I	Probability theory	2OUS5STPT1	02	30	36	1	12	40	60	100
							2	12			
							3	12			
	II	Probability Distribution	2OUS5STPD2	02	30	36	1	15	40	60	100
							2	09			
							3	12			
	III	Theory of Estimation	2OUS5STTE3	02	30	36	1	16	40	60	100
							2	10			
							3	10			
	IV	Demography and Vital Statistics	2OUS5STDV4	02	30	36	1	12	40	60	100
							2	12			
							3	12			
	V – DSE-I	Regression Analysis	2OUS5STRA5	02	30	36	1	12	40	60	100
							2	12			
							3	12			
		Econometrics	2OUS5STEC5	02	30	36	1	12	40	60	100
							2	12			
							3	12			
	VI-DSE-2	Operation research-II	2OUS5STOR6	02	30	36	1	18	40	60	100
							2	07			
							3	11			
		Design of Experiments	2OUS5STDE6	02	30	36	1	18	40	60	100
							2	07			
							3	11			
	VII-SEC	Statistical Computing using c-Programming	2OUS5STSCC7	02	30	36	1	18	40	60	100
							2	18			

Sem	Course Number	Course Title	Course Code	Credit	Hours	Periods (50 min)	Unit/ Module	Lectures (50 min)	Examination		
									Int. Marks	Ext. Marks	Total Marks
Theory											
VI	I	Survival Analysis	2OUS6STSAI	02	30	36	1	12	40	60	100
							2	12			
							3	12			
	II	Testing of hypothesis	2OUS6STTH2	02	30	36	1	16	40	60	100
							2	08			
							3	12			
	III	Stochastic Process	2OUS6STSQ3	02	30	36	1	12	40	60	100
							2	12			
							3	12			
	IV	Elements of actuarial science	2OUS6STEA4	02	30	36	1	12	40	60	100
							2	12			
							3	12			
	V – DSE-I	Data Mining	2OUS6STDM5	02	30	36	1	12	40	60	100
							2	12			
							3	12			
		Biostatistics	2OUS6STBIO5	02	30	36	1	11	40	60	100
							2	07			
							3	18			
	VI-DSE-2	Time series analysis	2OUS6STTS6	02	30	36	1	15	40	60	100
							2	07			
							3	14			
		Linear Model	2OUS6STLM6	02	30	36	1	18	40	60	100
							2	11			
							3	07			
	VII-SEC	Statistical Computing using R	2OUS6STSCR7	02	30	36	1	18	40	60	100
							2	18			

Evaluation pattern

Evaluation pattern: Theory
For each core course I, II, III, IV and DSE I and II and SEC
External (60 M) + Internal (40 M)
External: End Semester Examination
Paper Pattern: T. Y. B.Sc. Semester V/VI

External: 60 Marks **Duration: 2 hrs**

Question No.	Module	Marks (with max option)	Marks (Without option)
Q1	I	30 M	20 M
Q2	II	30 M	20 M
Q3	III	30 M	20 M

Internal: 40 Marks:

- 25 marks – MCQ type test using ICT technique
- 15 marks – assignment/workshop/Project

Evaluation pattern: Practical

Practical Evaluation: 50 Marks practical examination at the end of each semester per paper.

Course Title: Probability Theory
Course Code: 2OUS5STPTI
Core Course: I (Semester-V)
Credits: 02 (36 lectures)

Course Objective: To calculate probability of events by using laws of probability.
Course Outcome: By the end of this course, learner will able to

- Compute probabilities of events
- Understand and apply laws of probability
- Derive probability distribution of order statistics and sample range, sample median.

Module	Title and content	No. Of lectures
I	**Learning Objective:** • Explain basic concepts in probability and calculate the probability that an event will occur. • Understand four approaches to probability theory. • Compute the probability of events for more complex outcomes. • Understand conditional probability and Baye's Theorem. • Solve applications involving probabilities. **Learning Outcome:** By the end of this unit, learner will able to • Compute probabilities by applying appropriate probability laws. • Apply Baye's theorem and laws of probability to real life problems. **Probability** **a)** Sample Space, Sample point, Event: Impossible event, Sure event, Complementary event, Union and intersection of 'n' events, Mutually exclusive and Exhaustive events, pair-wise independent events **b)** Mathematical, Statistical, Axiomatic and Subjective probability. **c)** Theorems on Probability of realization of : (i) At least one; (ii) Exactly m; (iii) At least m, of N events $A_1, A_2, A_3 \ldots A_N$. Classical occupancy problems, Matching and Guessing problems. Problems based on them. **d)** Conditional Probability: Multiplication Theorem for two,	12L

three events. Independence of two/three events - complete and pair wise.

Bayes' theorem and its applications

2 **Learning Objective:** Understand the various laws in probability

Learning Outcome: By the end of this unit, learner will able to

- Apply different laws in probability
- Derive probability distribution.

Chebychey's Inequality, Weak Law of Large Numbers and Probability Generating Function 12L

a) If g(X) be a non-negative function of a random variable X, then for every $k > 0$, we have $P\{g(X) \geq k\} \leq E\{g(X)\}/k$.

b) Statement and proof of Chebychev's inequality (Discrete and Continuous random variables)

c) Weak law of large numbers (WLLN) for i.i.d. random variables having finite mean and variance and its applications.

d) Probability generating function and its properties.

3 **Learning Objective:**

- To understand meaning and importance of order statistics
- To derive distribution of order statistics
- To use order statistics in finding distribution of sample range

Learning Outcome: By the end of this unit, learner will able to

- Understand meaning and scope of order statistics.
- Determine the pdf of single and joint order statistics.
- Obtain pdf of sample range.

Order Statistics 12L

a) Definition of Order Statistics based on a random sample.

b) Derivation of:

i) Cumulative distribution functions of r^{th} order statistic.

ii) Probability density functions of the r^{th} order statistic.

iii) Joint Probability density function of the r^{th} and the s^{th} order statistic ($r<s$)

iv) Joint Probability density function of all n ordered statistics.

Probability density function of Median (in the case of odd sample sizes) and Range for Uniform and Exponential distributions.

References:

1. Feller W (2014) : An introduction to probability theory and it's applications, Volume:1, Third edition,Wiley Eastern Limited.
2. Robert V. Hogg & Allen T. Craig (1995) : Introduction to Mathematical Statistics, Fifth edition, Pearson Education (singapore) Pvt Ltd.
3. Alexander M Mood, Franklin A Graybill, Duane C. Boes: Introduction to the theory of statistics, Third edition ,Mcgraw- Hill Series .
4. Hogg R. V. and Tanis E.A.(2006) : Probability and Statistical Inference, Fourth edition, McMillan Publishing Company
5. S C Gupta & V K Kapoor (2011) : Fundamentals of Mathematical statistics, Eleventh edition, Sultan Chand & Sons.
6. Biswas S. (1992): Topics in Statistical Methodology, First edition, Wiley Eastern Ltd.
7. J. N. Kapur, H. C. Saxena(1963): Mathematical Statistics, Fifteenth edition, S. Chand and Company.
8. T.K.Chandra,D.Chatterjee (2003): A First Course In Probability, Second Edition,Narosa Publishing House.
9. Sheldon Ross: A first course in probability (6^{th} edition): Pearson Edu., Delhi
10. V.K.Rohatgi (2017) i: An introduction to probability theory and Statistics.

Course Title: Probability Distributions **Core Course:** II (Semester-V)
Course Code: 2OUS5STPD2 **Credits:** 02 (36 lectures)

Course Objective:

- Fitting of various continuous probability distributions and to study various real life situations.
- Identification of the appropriate probability model that can be used.

Course Outcome: By the end of this course, learner will able to

- To understand the nature of probability distributions.
- To apply the various continuous distributions for analyzing the data.
- To apply the truncated distributions in real life situations.

Module	Title and content	No. Of lectures

I **Learning Objective:** To understand the nature of probability distributions.

Learning Outcome: By the end of this unit, learner will able to

- Apply the various continuous distributions for analyzing the data.
- Fit truncated distribution to the practical applications.

Probability Distributions **15L**

a)Weibull distribution

$$f(x) = \frac{\beta}{\alpha}\left(\frac{x-\gamma}{\alpha}\right)^{\beta-1} exp\left\{\left(\frac{x-\gamma}{\alpha}\right)^{\beta}\right\} \qquad x \geq \gamma, \quad \alpha, \beta > 0$$

$$= \qquad otherwise$$

i) pdf , Notation : X ~ W (γ,α,β)
ii) Distribution function, quartiles.
iii) rth Moment about x = γ, mean and variance.
iv) Relation with exponential distribution.
v) Examples and problems.

b) Laplace distribution

$$f(x) = \frac{\lambda}{2} exp\{-\lambda|x-\mu|\} \quad -\infty < x < \infty, \quad -\infty < \mu < \infty, \lambda > 0$$

i) pdf, Notation : X ~ L (μ, λ)
ii) Nature of probability curve.
iii) Distribution function, quartiles.
iv) mgf, cgf, moments and cumulants, β1, β2, γ1, γ2.
v) Laplace distribution as the distribution of the difference of two i.i.d exponential variates with mean θ.
vi) Examples and problems.

c) Lognormal distribution :

$$f(x) = \frac{1}{(x-a)\sigma\sqrt{2\pi}} exp\left\{-\frac{1}{2\sigma^2}[log_e(x-a)-\mu]^2\right\} \quad x > a, -\infty < x < \infty, \sigma > 0$$

i) pdf , Notation : X~LN (a, μ, σ^2)
ii) Nature of the probability curve.
iii) Moments (r^{th} moment about x=a), first four moments, βI and γI coefficients, quartiles.
iv) Relation with N(μ, σ 2) distribution.
v) Examples and problems.

d) Cauchy distribution

$$f(x) = \frac{\lambda}{\pi}\frac{1}{\lambda^2+(x-\mu)^2} \quad -\infty < x < \infty, \quad -\infty < \mu < \infty, \lambda > 0$$

i) pdf, Notation : X~ C(μ, λ)
ii) Nature of probability curve.
iii) Distribution function, quartiles, non-existence of moments.
iv) Additive property for two independent Cauchy variates (Statement only), Statement of distribution of the sample mean.
v) Relationship with uniform and Student's 't' distribution.
vi) Examples and problems.

e) Pareto distribution

i) Pdf $f(x) = \frac{\alpha k^\alpha}{x^{\alpha+1}} \quad k \leq x < \infty, \quad \alpha, k > 0$
ii) cdf
iii) mgf

f) Truncated distribution : Truncated Normal distribution

i) Truncated distribution as conditional distribution, truncation to the right, left and on both sides.

ii) Normal distribution N(μ, σ 2) truncated

(i) to the left of X = a

(ii) to the right of X = b

(iii) to the left of X = a and to the right of X = b, its p.d.f and mean

iii) Examples and Problems.

2 **Learning Objective:**

- Understand extension of binomial distribution to Trinomial and Multinomial distribution.
- To derive marginal and conditional distribution and other properties of Trinomial and Multinomial distribution.

Learning Outcome: By the end of this unit, learner will able to

- Apply Trinomial and Multinomial distributions in real life problems.
- Understand properties of these distributions

Trinomial and Multinomial Distribution **9L**

a)Trinomial distribution: Definition of joint probability distribution of (X, Y). Joint moment generating function, moments μ_{rs} where r=O, 1, 2 and s=O, 1, 2. Marginal & Conditional distributions. Their Means & Variances. Correlation coefficient between (X, Y). Distribution of the Sum X+Y.

b) Extension to Multinomial distribution with parameters (n, p_1, p_2,...p_{k-1}) where $p_1+ p_2,+...p_{k-1}+ p_k= 1$. Expression for joint MGF. Derivation of: joint probability distribution of (X_i, Xj). Conditional probability distribution of X_i given $X_j = x_j$

3 **Learning Objective:**

- To demonstrate the univariate and bivariate normal distribution.
- To apply BND in real life problems.
- To derive test statistic for testing significance of population correlation coefficient.

Learning Outcome: By the end of this unit, learner will able to

- Understand the properties of BND.
- Find mgf, marginal and conditional distributions in BND.
- Apply BND in real life problems.
- Test significance of population correlation coefficient.

Bivariate Normal Distribution **12L**

a) Definition of joint probability distribution (X, Y). Joint Moment Generating function, moments μ_{rs} where r=O, 1, 2 and s=O, 1, 2. Marginal & Conditional distributions. Their Means & Variances. Correlation coefficient between the random variables.

b) Necessary and sufficient condition for the independence of X and Y. Distribution of aX + bY, where 'a' and 'b' are constants.

c) Distribution of sample correlation coefficient when $\rho = 0$.
d) Testing the significance of a correlation coefficient.
e) Fisher's z – transformation.
f) Tests for i) $H_0: \rho = \rho_0$ ii) $H_0: \rho_1 = \rho_2$
Confidence interval for ρ.

References:

1. Mood A. M, Graybill F. Bose D. C.(1974), Introduction to theory of Statistics (III Edn.) McGraw Hill Series
2. Hogg R.V. and Graig A. T.(1970) : Introduction to Mathematical Statistics (3rd Edn.) , Macmillan Publishing Co. Inc. New York.
3. S.C. Gupta and V.K. Kapoor : Fundamentals of Mathematical Statistics Sultan Chand and Sons, 88 Daryaganj New Delhi 2
4. Rohatgi V.K. (1975) An Introduction to probability Theory and Mathematical Statistics Wiley Eastern Ltd .New Delhi
5. Mukhopdhyay, P (1996). Mathematical Statistics, New Central Book Agency
6. Dasgupta A. (2010) Fundamentals of Probability: A first course, Springer, New York.

Course Title: Theory of Estimation
Course Code: 2OUS5STTE3

Core **Course:** III (Semester-V)
Credits: 02 (36 lectures)

Course Objective: To apply different methods of estimation and be able to select the best estimator based on various properties of the estimator.

Course outcome: By the end of this course a student will be able to

- Understand different types of estimation
- Properties of estimation
- Decide which estimate to select
- Obtain point estimate using different methods of estimation
- Calculate interval for the parameter within which parameter lies
- Estimate the parameter when parameter itself is a random variable

Module	Title and content	No. of Lectures
I	**Point Estimation and its Properties** **Learning Objective:** To estimate the unknown parameters and check its properties **Learning Outcome**: By the end of this unit, learner will able to • Understand the concept of point and interval estimation • Check whether the estimate is unbiased or not • Find a sufficient statistic • Calculate lower bound of variance of an estimate **a)** Notion of a parameter and parameter space. General problem of estimation, Definitions of Statistic, Estimator and Estimate. Concept of Point and Interval estimation. **b) Properties of estimator.** **i) Unbiasedness:** Definition of an unbiased estimator, biased estimator, positive and negative bias, examples (these should include unbiased and biased estimators for the same parameters). Proofs of the following results regarding unbiased estimators. • Two distinct unbiased estimators of $\phi(\theta)$ give rise to infinitely many unbiased estimators. • If T is an unbiased estimator of θ, then $\phi(T)$ is unbiased estimator of $\phi(\theta)$ provided $\phi(.)$ is a linear function.	16L

ii) Sufficiency: Definition of likelihood functions as a function of the parameter θ for a random sample from discrete and continuous distributions. Concept and definition of Sufficiency, definition of sufficient statistic through (i)conditional distribution (ii) Fisher Neyman factorization criterion.
Obtain sufficient statistic for standard distributions.

iv) Efficiency

Fisher information function: Amount of information contained in statistic T = T(XI, X2, ...,Xn). Statement regarding information in sample and in a sufficient statistic T.

Cramer- Rao Inequality: Statement and proof,

Cramer – Rao Lower Bound (CRLB), definition of minimum variance bound unbiased estimator (MVBUE) of ø(θ)

Comparison of variance with CRLB, relative efficiency of T_1 w.r.t. T_2 for unbiased and biased estimators. Efficiency of unbiased estimator T w.r.t. CRLB.

iv) Consistency: Definition. Proof of the following

An estimator is consistent if its bias and variance both tend to zero as the sample size tends to infinity.

If T is consistent estimator of θ and ϕ(.) is a continuous function then ϕ(T) is consistent estimator of ϕ (θ)

2 Methods of Estimation

Learning Objective: To estimate the parameters using different methods of estimation

Learning Outcome: By the end of this unit, learner will able to

- Estimate the parameter/s using appropriate method of estimation

a)Method of Maximum Likelihood Estimation (M.L.E.): 10L

Principle of M.L.E. Procedure to find M.L.E., Properties of M.L.E(without proof)

Derivation of M.L.E. for parameters of standard distributions (case of one and two unknown parameters).

M.L.E. of θ in uniform distribution over i) (O, θ) ii) (- θ, θ)

M.L.E. of θ in f(x ; θ)= Exp {-(x- θ)}, x > θ.

b) Method of Moments for one and two parameter family.

Definition, Derivation of moment estimators for standard distributions. Illustrations of situations where M.L.E. and Moment Estimators are distinct and their comparison using Mean Square Error.

c) Method of Minimum Chi-square and Modified Minimum

Chi-square. Definition, Simple examples

3 **Bayes Estimation and Interval Estimation** 10L

Learning Objective: To estimate the parameter when parameter itself is a random variable and to obtain the interval estimation for the parameter as per the level of significance mentioned.

Learning Outcome: By the end of this unit, learner will able to

- Estimate the parameter when parameter itself is a random variable
- Obtain the interval within which the parameter lies for small samples as well as for large samples

a)Bayesian Estimation: Prior distribution, Posterior distribution, Loss function, Risk function, Baye's solution under Squared Error Loss Function (SELF) and Absolute Error Loss function.

b) Interval Estimation: Concept of Confidence Interval and Confidence Limits. Derivation of 100(1-α) % equal tailed confidence interval

i) For the parameters μ, $\mu_1 - \mu_2$ (Population variance(s) known / unknown), σ^2, σ_1^2/σ_2^2 (Normal distribution).

ii) Based on asymptotic property of M.L.E.

References:

1. R.V.Hogg, A.T. Craig (1995): Introduction to Mathematical Statistics, Fifth Edition, Prentice Hall Of India/ Phi
2. R.V.Hogg, E. A.Tannis (2011): Probability and Statistical Inference, Pearson Education.
3. Rohatgi V.K. and EhsanesSaleh A. K. MD. (2003). An Introduction to Probability Theory and Mathematical Statistics, (Wiley Eastern, 2nd Ed.)
4. John E. Freund's Mathematical Statistics (2001): Fifth Edition; Phi (Eastern Eco. Ed.).
5. P.G. Hoel: Introduction to Mathematical Statistics; Fourth Edition; John Wiley & Sons Inc.
6. S.C. Gupta, V.K. Kapoor (2016): Fundamentals of Mathematical Statistics; Eighth Edition; Sultan Chand & Sons.
7. J.N. Kapur, H.C. Saxena (2014): Mathematical Statistics; First Edition; S. Chand & Company Ltd.

Course Title: Demography and Vital Statistics **Core Course:** IV (Semester-V)

Course Code: 2OUS5STDV4 **Credit:** O2 (36 lectures)

Course Objective: To be able to identify appropriate sources of data, perform basic demographic analyses using various techniques and ensure their comparability across populations. And to able to produce population projections and interpret the information gathered by the different demographic methods.

Course Outcome: By the end of this course a student will be able to

- Comprehend the basic concepts and definitions in Demography
- Familiar with different concept of official statistics of India
- Identify the various sources of data in Demography
- Describe the population growth scenario of the world, India and its states
- Understand construction of different columns of life tables
- Population projection for specific population

Module	Title and Contents	No. of Lectures
I	**Learning Objective:** To introduce students the basic concepts of demography and sources of demographic data **Learning Outcome:** By the end of this unit, learner will able to • To introduce official statistics • Understand importance of Demography and its linkages with health • Understand History of Population changes of world • Different sources of demographic data **Introduction to demography and sources of demographic data** **a)**Introduction to demography and the link with health sciences Definition and Scope; historical trends in population situation in the world; Present population situation in the world and in the world and in developed countries **b)** Introduction to Indian and International statistical systems. Role, function and activities of central and state statistical organizations, organization of large scale sample surveys, role of national sample survey organization general and special data dissemination systems. **c)**Population census; Uses and limitations; various sources of nuptiality, fertility and mortality data and its quality; Vital registration, National Sample Survey Sample Registration System	12L

and Demographic Health Surveys (DHS) and other sources

2 **Learning Objective:** To impart skills in the basic measures of fertility, mortality and migration

Learning Outcome: By the end of this unit, learner will able to

- Understand basic measures of fertility, mortality and migration
- Application of these measure for demographic research

Basic Measures of Fertility, Mortality and Migration 12L

a)Basic Concepts and Measures of Current/Period Fertility/Fecundity/Natural Fertility Measures of reproduction(GRR, NRR)

Age pattern of fertility and its importance in understanding fertility transition

b)Concepts and Basic Measures of Mortality

Definition of deaths and fetal deaths according to WHO; Need and Importance of the study of Mortality;

Some basic measures: - crude death rate (CDR) and Age-Specific Death Rates (ASDRs)- their relatives merits and demerits

Techniques of standardization Rates/Ratio

Child and Infant mortality estimation procedure, calendar/cohort concept of rate

c)Measures of pregnancy wastage

Historic of pattern of age sex mortality

d)Concept of mobility and migration, sources and quality of data, types of migration, census definition of migrants, limitations

Measures of Migration – Direct estimation of lifetime and inter-censal migration rates from census data

International migration

3 **Learning Objective:** To Acquire skills to use life tables and getting knowledge of different population projection methods

Learning Outcome: By the end of this unit, learner will able to

- To understand and construct different columns of life tables
- To estimate and project the population of specific regions

Life table and Population estimation 12L

a)Basic concept of a life table; types and forms of life table;

Brief history of life tables; Model life tables; Anatomy of life table; uses of life table in demographic analysis

b)Construction of Life tables based on Age- specific death Rates

(ASDRs)

Underlying assumptions of life table construction using ASDRs of a community during a specified period; Methods of life table Construction—Conventional approach, and those proposed by Greville and Chiang.

c) Concepts of population projections; population estimates, forecasts and projections, uses of population projections.

Methods of interpolation; extrapolation using linear, exponential, polynomial, logistics, Gompertz curves and growth rate models

References:

1. Guide to Official Statistics, CSO, 1999.
2. Statistical System in India, CSO, 1995
3. Jacob S. Siegel and David a. Swanson (2004): The Methods and Materials of Demography, Second Edition, Chapters 1, 2, 3, 7, 9,10, Elsevier Science, USA.
4. Asha A. Bhende and Tara Kanitkar, (2003), Principles of Population Studies, Sixteenth Revised Edition, Himalaya Publishing House, Mumbai.
5. John R. Weeks, (2005), Population: An Introduction to Concepts and Issues, Nineth Edition, Wadsworth Publishing Company, Belmont, California.
6. Ram, F. and K.B. Pathak (1998): Techniques of Demographic Analysis,2nd Ed, Himalaya Publishing house, Bombay(Chapters 2 & 3).
7. United Nations, (1974): Methods of Measuring Internal Migration, Manual VI, UN, New York.
8. United Nations, (2004): World Urbanization Prospects, The 2003 Revision, New York.
9. Makridakis, S. Steven C., Wheelwright, and Rob J. Hyndman (1998): Forecasting: Methods and Applications, New York: John Wiley and Sons, p607-.
10. Jacob S. Siegel and David a. Swanson (2004): The Methods and Materials of Demography, Second Edition, Chapters 1, 2, 3, 7, 9,10, Elsevier Science, USA.
11. Murray C. J. L., J. A. Salomon, C. D. Mathers and A. D. Lopez (2002). Summary Measures of Population Health: Concepts, Ethics, Measurement and Applications. WHO, Geneva.

Discipline Specific Elective-I (Sem-V)

Course Title: Regression Analysis
DSE-I Course: V (Semester-V)
Course Code: 2OUS5STRA5
Credits: O2 (36 lectures)

Course Objective: To explain the variation in one variable (called dependent variable) based on the variation in one or more other variables (called independent variable).

Course Outcome: By the end of this course, learner will able to

- Fit the simple, Multiple and Logistic Regression models.
- Model building, residual diagnostics, corrective measures and polynomial regression model.
- Test the hypothesis of model parameters, AIC and BIC criteria.
- Interpret the output produced by glm command in R.

Module	Title and content	No. Of lectures
I	**Learning Objective**: To predict the value of a dependent variable based on the independent variable. Learning Outcomes: By the end of this unit, learner will able to • Terminology and data requirement for conducting a regression analysis. • Estimate mean value and predicted value. • Interpretation & use of the scatter plots produced by lm command in R. • How to evaluate the assumptions of regression analysis and know what to do if the assumptions are violated. **Simple Linear Regression Model:** **a)** Review of simple linear regression model: $Y = \beta_O + \beta_1 X + \varepsilon$, where ε is a continuous random variable with $E(\varepsilon) = O$, $V(\varepsilon) = \sigma_2$. Estimation of β_O and β_1, by the method of least squares. **b)** Properties of estimators of β_O and β_1. **c)** Estimation of σ_2. **d)** Assumption of normality of ε. Tests of hypothesis of β_1. **e)** Coefficient of determination. **f)** Residual analysis: Standardized residuals, residual plots.	12L

g) Detection and treatment of outliers.

h) Interpretation of four plots produced by lm command in R.

2 **Learning Objective**: To establish the linear equation that best predicts values of a dependent variable 'Y' using more than one explanatory variable from a large set of potential predictors $\{x_1, x_2, \ldots\ldots, x_k\}$

Learning Outcomes: By the end of this unit, learner will able to

- Construction of multiple regression equation.
- Calculation of predicted value of dependent variable using multiple regression equation

Multiple Linear Regression Model: **12L**

a) Review of multiple linear regression model $Y = \beta_0 + \beta_1 X_1 + \ldots + \beta_p X_p + \varepsilon$, where ε is a continuous random variable with $E(\varepsilon) = 0$, $V(\varepsilon) = \sigma_2$. Estimation of regression parameters β_0, β_1, . . . and β_p by the method of least squares, obtaining normal equations, solutions of normal equations.

b) Estimation of σ_2.

c) Assumption of normality of ε. Tests of hypothesis of regression parameters.

d) Interval estimation in simple linear regression model.

e) Variable selection and model building.

f) Residual diagnostics and corrective measures such as transformation of response variable, weighted least squares method.

g) Polynomial regression models.

3 **Learning Objective:** To state the circumstances under which logistic regression should be used instead of multiple regression.

Learning Outcome: By the end of this unit, learner will able to

- understand when it is relevant to choose logistic regression.
- Identify the type of dependent and independent variable used in the application of logistic regression.
- Correctly interpret the result of logistic regression by glm command in R.

Logistic Regression Model: **12L**

a) Binary response variable, Logit transform, estimation of parameters, interpretation of parameters.

b) Tests of hypotheses of model parameters, model deviance.

c) AIC and BIC criteria for model selection.

d) Interpretation of output produced by glm command in R.

e) Multiple logistic Regression

References:

1. Draper, N. R. and Smith, H. (1998). Applied Regression Analysis (John Wiley) Third Edition.
2. Hosmer, D. W. and Lemeshow, S. (1989). Applied Logistic Regression (Wiley).
3. Montgomery, D. C., Peck, E. A. and Vining, G. G. (2003). Introduction to Linear Regression Analysis (Wiley).
4. Neter, J., W., Kutner, M. H.; Nachtsheim, C.J. and Wasserman, W.(1996). Applied Linear Statistical Models, fourth edition, Irwin USA.
5. Chatterjee. S. and Handi A.S.(2012): Regression Analysis by Example ,5th Edition,Wiley.
6. Kleinbaum G. and Klein M. (2011) : Logistic Regression, IIIrdEdition A Self learning text, Springer.

Course Title: Econometrics
Course Code: 2OUS5STEC5
DSE-I Course: V (Semester-V)
Credits: 02 (36 lectures)

Course Objective: To deepen and broaden student's knowledge and understanding of basic econometric techniques needed for empirical quantitative analysis.

Course Outcome: By the end of this course, learner will able to

- Describe consumer behaviour.
- Apply concepts of statistics in economic models.

Module	Title and content	No. Of Lectures
1	**Learning Objective:** To illustrate different models **Learning Outcomes:** At the end of the unit, learners will be able to i) Estimate the parameters of the model ii) State the properties of estimators iii) Apply tests of significance **Econometric Methods and Models** a) Definition & Scope b) Nature of Econometric Approach c) Methodology & Econometric Research d) Econometric Models e) Single Equation Models	12L
2	**Learning Objective:** To familiarize students with application of single equation techniques. **Learning Outcomes:** At the end of the unit, learners will be able to i) Estimate the demand & production functions ii) Apply concepts of forecasting **Application of Single Equation Technique** a) Heteroscedasticity b) Multicollinearity c) Autocorrelation d) Statistical Estimation of Demand Function e) Statistical Estimation of Production Function	12L
3	**Learning Objective:** To apply statistics in dynamic models **Learning Outcomes:** At the end of the unit, learners will be able to i) State the assumptions ii) Test the validity of the assumptions. iii) Analyse the closed & dynamic model.	

Input-Output Analysis **12L**

a) The Inter-Industry Accounting System
b) Assumptions
c) Closed Model
d) Dynamic Model

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1. P. V. Borwankar, Econometrics: An Introductory Analysis, Sheth Publishers pvt. Ltd.
2. Gujarati, Damodar and Sangeetha (2011), Basic Econometrics, McGraw Hill, Fifth Edition
3. Mankiw, N. G. (2002), Principles of Economics, Thomson Asia Pte. Ltd., Singapore.
4. Pindyck, R, Rubinfeld and Mehta (2011), Microeconomics, Pearson Prentice Hall, 7th Edition
5. Salvatore, D., (2006) Microeconomics: Theory and Applications, Oxford University Press, New Delhi.
6. D'Souza Errol, (2012), Macroeconomics, Dorling Kindersley India pvt. Ltd.- Pearson Education, second edition Mankiw
7. Edward Dowling (2011), Schaum's Outline of Introduction to Mathematical Economics, McGraw Hill Education, Third Edition

Discipline Specific Elective-2 (Sem-V)

Course Title: Operations Research **DSE-2 Course:** VI (Semester-V)
Course Code: 2OUS5STOR6 **Credits:** 02 (36 lectures)

Course Objective: To help students make correct decisions in real life market circumstances.

Course Outcome: By the end of this course, learner will able to

- Estimate the no. of units to be kept in stock keeping in view the cost constraints in various situations.
- Select appropriate replacement policy.
- Make the best decision under different decision-making situations.

Module	Title and content	No. Of lectures
I	**Learning Objective:** To set up various models under deterministic & probabilistic situations in maintaining appropriate stock & minimizing cost. **Learning Outcomes:** At the end of the unit, learners will be able to • Identify different types of cost involved. • Compute quantity of units to be produced or to be kept in inventory. • Measure the minimum cost/expected cost. • Specify the time for the next order. **INVENTORY CONTROL** Introduction to Inventory Problem **a) 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. **b) Probabilistic models:** Single period with (i) Instantaneous demand (discrete and continuous) without setup cost. (ii) Uniform demand (discrete and continuous) without set up cost.	18L

2 **Learning Objective:** To enable learners to plan for replacement of items taking in view the various cost constraints.

Learning Outcomes: At the end of the unit, learners will be able to

- Formulate cost functions under different situations.
- Compute the time of replacement of items.
- Calculate the costs for individual and group replacements.
- Choose the appropriate replacement policy.

REPLACEMENT 7L

a) Replacement of items that deteriorate with time and value of Money i) remains constant ii) changes with time.

b) Replacement of items that fail completely: Individual replacement and Group replacement policies.

3 **Learning Objective:** To select the best decision under different decision making situations.

Learning Outcomes: At the end of the unit, learners will be able to

- Demonstrate the various decision making criteria.
- Employ the correct decision criteria.
- Critically evaluate the decision taken under a given situation.

DECISION THEORY 11L

Decision making under uncertainty:

a) Laplace criterion b) Maximax (Minimin) criterion

c) Maximin (Minimax) criterion d) Hurwicz _ criterion

e) Minimax Regret criterion.

Decision making under risk: Expected Monetary Value criterion, Expected Opportunity Loss criterion, EPPI, EVPI. Bayesian Decision rule for Posterior analysis. Decision tree analysis along with Posterior probabilities.

References:

1. N. D. Vora : Quantitative Techniques in Management, Third edition, McGraw Hill Companies
2. Bannerjee B. : Operation Research Techniques for Management, First edition, Business books
3. Bronson R. : Theory and problems of Operations research, First edition, Schaum's Outline series
4. Kantiswarup, P.K. Gupta, Manmohan : Operations Research, Twelth edition, Sultan Chand & sons
5. S. D. Sharma: Operations Research, Eighth edition, Kedarnath Ramnath & Co.

Course Title: Designs of experiment DSE-2 **Course:** VI (Semester-V)
Course Code: 2OUS5STDE6 **Credits:** O2 (36 lectures)

Course Objective: To introduce students to general block designs with particular cases and importance of confounding in factorial designs.
Course Outcome: By the end of this course, learner will able to

- Choose the most efficient design based on its properties and optimality conditions.
- Apply BIBD & Split-Plot design in appropriate situations.
- Justify the use of total and partial confounding and analyse the design accordingly.

Module	Title and content	No. Of lectures
1	**Learning Objective:** Explain the analysis of a general block design and its properties. **Learning Outcomes:** At the end of the unit, learner will be able to • Analyse any general block design. • Identify the properties of any design. • State whether the design satisfies the optimality conditions. • Choose the most efficient design. **Generalized block design** a)An example b)Statistical analysis of GBD c) Introduction to C-matrix d) Properties of design-Connectedness, balancedness and Orthogonal. e) Optimality of designs- A, D & E.	18L
2	**Learning Objective:** Analyse BIBD & Split-Plot design **Learning Outcomes:** At the end of the unit, learner will be able to • Check whether BIBD have the properties of connectedness, balancedness and orthogonality. • Justify the use of Split-Plot design in appropriate situations. • Analyse Split-Plot design to test for main effects, sub-effects & interaction effects. **BIBD & Split-plot** a) Analysis of BIBD.	7L

b) The Split –plot design-An example
c) Statistical analysis of Split-plot design.

3 **Learning Objective:** Discuss the relevance of blocking & confounding and its analysis

Learning Outcomes: At the end of the unit, learner will be able to

- Differentiate between total confounding & partial confounding.
- Confound a 2^k factorial design in 2^p blocks.
- Identify the confounded treatments.
- Analyse the confounded design
- Partially confound treatments.
- Estimate the confounded treatments in case of partial confounding.
- Analyse partially confounded design.

2^kfactorial design **11L**

a) A single replicate of the 2^k design.
b) Blocking a replicated 2^kfactorial design
c) Confounding in the 2^kfactorial design.
d) Partial confounding.

References:

1. Montgomery D.C., Design and Analysis of Experiment 8th Edition, John Wiley & Sons.
2. Chakrabarti M.C., Mathematics of Design and Analysis of Experiments.
3. Raghava rao D., Construction and Combinatorial Problems in Design of Experiments.
4. Das. M.M. and Giri N.C., 1986, Design and Analysis of Experiments. New Age International (P) Limited
5. Fisher R.A., Design of Experiments.
6. Dean Voss :-Design and Analysis of Experiments
7. S.C.Gupta and V.K.Kapoor, (2001), Fundamentals of Applied Statistics:; 3rd Edition, Sultan Chand and Sons.
8. B.J. Winer, Statistical Principles in Experimental Design, McGraw Hill Book Company
9. W.G. Cochran and G.M.Cox, Experimental Designs: Second Edition, John Wiley and Sons.
10. Oscar Kempthorne, The Design and Analysis of Experiments, John Wiley and Sons
11. Walter T Federer, Experimental Design, Theory and Application, Oxford & IBH Publishing Co. Pvt.

Skill Enhancement Course (Sem-V)

Course Title: Statistical Computing using c- programming **Course:** VII (Semester-V)
Course Code: 2OUS5STSCC7 **Credits:** O2 (36 lectures)

Course Objective: To write c- programs
Course Outcome: By the end of this course, learner will able to

- Write control and looping statements
- Construct c-user-defined functions and c-structures

Module	Title and Content	No. Of lectures
I	**Learning Objective:** To develop simple c-programs **Learning Outcome:** By the end of this unit, learner will able to • Recognise different types of c-variables, constants and operators • Write various types of input/output statements • Distinguish different types of predefined functions • Write control statements • Write looping statements • Design simple c-programs **C- Variables, Constants, Operators, Predefined functions, I/O statements, Control and Looping statements :** **a)** Structure of a C program, Execution of C Program, Concept of header files, Use of comments. **b)** Variables, Constants and operators: c-character set, Constants, Keywords, identifiers and Variables, Data types, Data type Qualifiers, Declaration of variables, Assigning values to variables, Escape sequences, Defining symbolic constants, Declaring and initializing String variables, c-operators: Arithmetic, Relational, Logical, Assignment, Increment and Decrement, Conditional, Operator Precedence and Associativity, C Expressions – Arithmetic expressions, Evaluation of expressions, Automatic and Explicit type conversion. **c)** I/O statements: Formatted I/O: printf(), scanf(). Character I/O format: getch(), getche(), getchar(), getc(), gets(), putchar(), putc(), puts(). **d)** Predefined functions – isdigit(), isupper(), islower() and ispunct() functions in header file <ctype.h>; sin(), cos(), tan(),	18L

exp(), ceil(), floor(), log(), log10(), abs(), pow() and sqrt() functions in header file <math.h>

e) Control statements for decision making: if statement, if...else statement, else... if statement, nested if statement, switch statement, goto statement

f) Looping statement: while loop, do... while, for loop, nested loop. Loop interruption statements: break, continue.

2 **Learning Objective:** To develop advance c-programs

Learning Outcome: By the end of this unit, learner will able to

- Recognise different types of c-string functions
- Distinguish between arrays and structure
- Distinguish between simple variables and pointers
- Write user-defined functions
- Design advance c-programs

String handling, Arrays, Pointers, User-defined functions, Storage classes and structure: 18L

a) String functions (strcpy, strcat, strchr, strcmp, strlen, strstr, atoi, atof).

b) Arrays: (One and two dimensional), declaring array variables, initialization of arrays, accessing array elements.

c) User-defined Functions: Function definition, return statement, calling a function, Recursion functions for factorial, Fibonacci sequence, exponential function, G.C.D.

d) Storage classes: Automatic variables, External variables, Static variables, Register variables.

e) Structure: Declaration of structure, reading and assignment of structure variables, Array of structures.

Course Title: Survival Analysis
Course Code: 2OUS6STSAI
Core Course: I (Semester-VI)
Credits: 02 (36 lectures)

Course Objective: To acquaint students with the concepts such as Survival analysis, Reliability theory, Censoring and Non-parametric estimation of Survival function.

Course Outcome: By the end of this course, learner will able to

- Find survival functions and hazard functions from the survival data
- Compute reliability of the system
- Understand different types of censoring
- Compute K-M estimator of survival function

Module	Title and content	No. Of lectures
1	**Learning Objective:** • To explain basic concepts in survival analysis • Applications of survival analysis in real life problems **Learning Outcome:** At the completion of this unit students will able to: • Understand the need of Survival analysis • Find survival functions and hazard functions from the survival data • Apply concepts of survival analysis in real life problems **Introduction to Survival analysis and Ageing properties** **a)** Basic concepts: pdf, cdf, survival function, Hazard function, cumulative hazard function **b)** Definitions of IFR (Increasing Failure Rate), DFR (Decreasing Failure Rate), CFR (Constant Failure Rate), NBU (New Better than Used) and NWU (New Worse than Used) components of lifetime distributions, Mean time to failure (MTTF) **c)**Hazard models **d)**Data plots	12L
2	**Learning Objective:** To enable students with concept of Reliability of the performance of the component **Learning Outcome:** At the end of this unit Students will be able to: • Compute reliability of the system • Understand use of reliability in real life **Reliability theory** **a)** Concept of Reliability **b)** Parallel structure, Series structure, k out of n structure	12L

c) Equivalent structure for any system: Path set, Minimal path set, Path vector, Minimal path vector, cut set, Minimal cut set, Cut vector, Minimal cut vector

d) Reliability of the system of independent components

3 **Learning Objective:** To enable students with concept of censoring, Non-parametric estimation of survival function

Learning Outcome: At the completion of this unit students should be able to:

- Understand the concept of censoring
- Understand different types of censoring
- Compute K-M estimator of survival function
- Use of these concepts in real life problems

Censoring and Non-parametric estimation of Survival function **12L**

a) Concept of censoring: Type-I, Type-II and Random censoring

b) Non-parametric estimation of survival function: Kaplan-Meier (KM) estimator, Properties of KM estimator, Approximate mean and variance of KM estimator, Approximate confidence intervals for survival function

c)Q-Q plot for survival function

References:

1. Smith P.J. (2002): Analysis of Failure and Survival data. Florida: CRC Press
2. Deshpande J.V. and Purohit S.G. (2005): Life Time Data: Statistical Models and Methods Pune: Word Scientific
3. Barlow R.E. and Proschan F (1965): Mathematical theory of reliability New York: John Wiley
4. Barlow R.E. and Proschan F (1975): Statistical theory of reliability and life testing: Probability models New York: Holt, Rinehart and Winston
5. Ross S.M. (1993): Introduction to Probability Models United States: Academic Press (Elsevier)
6. Cox DR, Oakes D.(2001): Analysis of survival data London, England: Chapman and Hall

Course Title: Testing of hypothesis Core **Course:** II (Semester-VI)
Course Code: 2OUS6STTH2 **Credits:** O2 (36 lectures)

Course Objective: To define and distinguish between various types of Parametric and non-parametric methods.

Course Outcome: By the end of this course, learner will able to

- State parametric and non-parametric statistical hypothesis
- Formulate test-statistic formula when sample size is not fixed in advance and also for fixed sample size
- Write decision about acceptance and rejection of statistical hypothesis when sample size is not fixed in advance and also for foxed sample size.

Module	Title and content	No. Of lectures
I	**Learning Objective:** To recognise whether there is enough statistical evidence in favour of a certain belief, or hypothesis, about the form of the population or parameters of the population using parametric methods for fixed sample size. **Learning Outcome:** By the end of this unit, learner will able to • Define null hypothesis, alternative hypothesis,level of significance, test statistic, p value, and statistical significance. • Differentiate type-I and type-II errors • Differentiate most powerful and uniformly most powerful test • Set up best critical region for simple alternative hypothesis and composite alternative hypothesis. **Most Powerful Tests, Uniformly Most Powerful & Likelihood Ratio Tests:** **a)** Definitions and illustrations of i) Simple hypothesis ii) Composite hypothesis iii)Null Hypothesis iv) Alternative Hypothesis v)Test of hypothesis vi) Critical region vii) Type I and Type II errors viii) Level of significance ix) p-value x) Size of the test xi) Power of the test xii) Power function of a test xiii) Power curve. **b)** Definition of most powerful test of size α for a simple hypothesis against a simple alternative hypothesis. Neyman-Pearson fundamental lemma. **c)** Definition, Existence and Construction of Uniformly most powerful (UMP)	16L

d) Likelihood ratio principle: Definition of test statistic and its asymptotic distribution (statement only). Construction of LRT for the mean of Normal distribution for (i) Known σ^2 (ii) Unknown σ^2(two sided alternatives).LRT for variance of normal distribution for (i) known μ (ii) unknown μ (two sided alternatives hypothesis)

2 **Learning Objective:** To recognise whether there is enough statistical evidence in favour of a certain belief, or hypothesis, about the form of the population or parameters of the population using parametric methods when sample size is not fixed in advance.

Learning Outcome: By the end of this unit, learner will able to

- Compare testing of hypothesis for fixed sample size and when sample size is not fixed in advance.
- Establish best critical region under various distributions when sample size is not fixed in advance
- Draw graph to represent critical region and acceptance region and interpret the information.

Sequential Probability Ratio Test (SPRT) **O8L**

a)Sequential test procedure for testing a simple null hypothesis against a simple alternative hypothesis. Its comparison with fixed sample size (Neyman-Pearson) test procedure.

b)Definition of Wald's SPRT of strength (α, β).

c)Problems based on Bernoulli, Binomial, Poisson, Normal, Exponential distributions.

d)Graphical /tabular procedure for carrying out the tests.

3 **Learning Objective:** To recognise whether there is enough statistical evidence in favour of a certain belief, or hypothesis, about the form of the population or parameters of the population using non-parametric methods.

Learning Outcome: By the end of this unit, learner will able to

- Distinguish distribution-free tests and parametric test for testing statistical hypotheses
- Construct most common methods and techniques of nonparametric statistics(signed tests, ranked tests, run test etc.).

Non-Parametric Tests **12L**

a) Need for non parametric tests. Distinction between a parametric and a non parametric test .Concept of a distribution free statistic.

b) Single sample and two sample Non-parametric tests. (i) Sign test (ii) Wilcoxon's signed rank test (iii) Median test (iv) Mann–Whitney test (v) Run test.

c) Assumptions, justification of the test procedure for small & large samples.

References:

1. Hogg R.V. and Craig A.T: Introduction to Mathematical Statistics Fourth edition London Macmillan Co. Ltd.
2. Hogg R.V. and Tanis E.A.: Probability and Statistical Inference. Third edition Delhi Pearson Education.
3. Lehmann, E. L: Testing of Statistical Hypothesis, Wiley &sons
4. Rao, C. R.: Linear Statistical Inference,
5. Daniel W.W.: Applied Non Parametric Statistics First edition Boston-Houghton Mifflin Company.
6. Wald A.: Sequential Analysis First edition New York John Wiley & Sons
7. Biswas S.: Topics in Statistical Methodology. First edition New Delhi Wiley eastern Ltd.
8. Gupta S.C. and Kapoor V.K.: Fundamentals of Mathematical Statistics Tenth edition New Delhi S. Chand & Company Ltd.
9. Sanjay Arora and BansiLal: New Mathematical Statistics, SatyaPrakashan, New Market, New Delhi, 5(1989).
10. Statistical Methods Using R Software V. R. Pawagi and Saroj A.Ranade; Nirali Publications.

Course Title: Stochastic Processes and Queuing theory **Core Course:** III (Semester-VI)
Course Code: 2OUS6STSQ3 **Credits:** O2 (36 lectures)

Course Objective: To construct different types of stochastic processes and queuing models.

Course Outcome: By the end of this course, learner will able to

- Differentiate various types of birth and death processes
- Identify Markov processes and Markov chains
- Setup different types of queuing models

Module	Title and content	No. Of lectures
1	**Learning Objective:** To differentiate different types of stochastic processes **Learning Outcomes:** At the end of the unit, learners will be able to • Recognise different birth processes • Recognise different death processes **STOCHASTIC PROCESSES** a)Definition of stochastic process. b)Postulates and difference differential equations for : i)Pure birth process ii)Poisson process with initially 'a' members, for a =O and a >O iii)Yule Furry process iv)Pure death process v)Death process with $\mu_n=\mu$ 15 Lectures vi)Death process with $\mu_n=n\mu$ vii)Birth and death process viii)Linear growth model. c) Derivation of $P_n(t)$, mean and variance where ever app	12L
2	**Learning Objective:** To know applications of Markov chain **Learning Outcomes:** At the end of the unit, learners will be able to • To Understand the concept of dependence • To calculate probabilities from one step transition probability matrix • To apply concept of Markov Chain in real life problems. **MARKOV CHAIN** **a)** Definition of Markov Chain, transition probability matrix, order of Markov chain, first order Markov property, Markov chains (MC), finite MC, time homogeneous M.C. b) One step transition probabilities, and transition probability matrix (t.p.m.), stochastic matrix, Chapman Kolmogorov equation, n-step transition probability matrix , n-step t.p.m. of	12L

two state MC. and some typical t. p. m. initial distribution,

c) Finite dimensional distribution functions , partial sum (and functions)of independent and identically distributed random variables as Markov chain, illustrations such as random walk, Gambler's ruin problem, Ehrenfest chain

d)Communicating states , first return probability, probability of ever return Classification of states, as persistent and transient states, irreducible MC

3 **Learning Objective:** To identify different types of queuing models

Learning Outcomes: At the end of the unit, learners will be able to

- Calculate steady state probabilities for birth and death processes
- Identify different queuing models

QUEUING THEORY 12L

a) Basic elements of the Queuing model.

b) Roles of the Poisson and Exponential distributions.

c) Derivation of Steady state probabilities for birth and death process.

d) Steady state probabilities and various average characteristics for the following models: (i) (M/M/1) : (GD/ ∞ /∞) (ii) (M/M/1) : (GD/ N /∞) (iii) (M/M/c) : (GD/∞/∞) (iv) (M/M/c) : (GD/ N /∞) (v) (M/M/∞) : (GD/ ∞ /∞)

References:

1. J Medhi: Stochastic Processes, Second edition, Wiley Eastern Ltd.
2. Hoel , P.G.,Port, S.C. ,Stone, C.J. (1972) : Introduction to stochastic processes
3. Kantiswarup, P.K. Gupta, Manmohan : Operations Research, Twelth edition, Sultan Chand & sons
4. S. D. Sharma: Operations Research, Eighth edition, Kedarnath Ramnath& Co.

Course Title: Elements of actuarial science
Course Code: 2OUS6STEA4
Core Course: IV (Semester-VI)
Credits: 02 (36 lectures)

Course Objective:

- To differentiate different types of annuities, assurance plan.
- To calculate present and accumulated value of money under different types of annuities
- To calculate and compare level annual premium under different assurance plan

Course Outcome: By the end of this course, learner will able to

- Establish relation between nominal and effective rate of interest
- Formulate Single premium and level annual premium under different assurance plan

Module	Title and content	No. Of lectures
I	**Learning Objective:** To compute value of money, at different time periods, using nominal and effective rate of interest, for annuity certain **Learning Outcome :** By the end of this unit, learner will able to • Compute accumulated value using simple and compound interest • Find discounted value • Correlate between nominal and effective rate of interest • Define different types of annuity certain • Determine present value and accumulated value for different types of annuity certain • Assess interest and principal contained in m^{th} yearly instalment • Assess principal outstanding at the end of m year **Annuity Certain** **a)** Simple and compound Interest, relation between nominal and effective rate of interest , present value (p.v.), accumulated value (a.v.), discount and discounted value, p.v. and a.v. for varying rates of interest, equation of value **b)** Annuities: different types of annuity, derivations for p.v. and a.v. of different types of annuities **c)** Variable annuity: p.v. and a.v. of an increasing annuity of different types, p.v. and a.v. of an increasing annuity certain where successive instalments form arithmetic progression/geometric progression.	12L

d)p.v. and a.v. of annuity, where i) payments are made p-times a year ii) payments of amount y are made at each interval of 'r' years.

e) Redemption of loan: Derivation for i) interest contained in m^{th} yearly instalment ii) principal contained in the m^{th} yearly instalment iii) principal outstanding at the end of m years

2 **Learning Objective:** To compute value of money, at different time periods, using nominal and effective rate of interest, for life annuity.

Learning Outcome: By the end of this unit, learner will able to

- Write commutation functions
- Define different types of life annuities
- Determine present value for different types of life annuities in terms of commutation functions

Life annuity **12L**

a) Commutation functions, p.v. of an immediate life annuity and life annuity due, p.v. of differed immediate life annuity and life annuity due

b)p.v. of temporary immediate life annuity and life annuity due, p.v. of deferred temporary immediate life annuity and life annuity due

c)p.v. of increasing temporary immediate life annuity and life annuity due

d) Life annuity payable m times in a year

3 **Learning Objective:** To compute assurance benefits and level annual premium under different assurance plan

Learning Outcome: By the end of this unit, learner will able to

- Recognise different assurance plans
- Determine single premium under different assurance plans
- Determine level annual premium under different assurance plans

Assurance benefits and Net premiums **12L**

a) Derivations for p.v. of benefits (single premium) under various assurance plans i) temporary assurance ii) Whole life assurance iii) Pure endowment assurance iv) Endowment assurance v) Double endowment assurance vi) Increasing temporary assurance vii) Increasing whole life assurance viii) Special endowment assurance

ix) Deferred temporary assurance x) deferred whole life assurance

b) Derivations for level annual premium under various assurance plans i) temporary assurance ii) Whole life assurance iii) Pure endowment assurance iv) Endowment assurance v) Double endowment assurance

References:

1) Neill A. : Life Contingencies, First edition, Heineman educational books London
2) Dixit S.P., Modi C.S., Joshi R.V. : Mathematical Basis of Life Assurance, First edition Insurance Institute of India.
3) Gupta S. C. &. Kapoor V. K.: Fundamentals of Applied Statistics, Fourth edition, Sultan Chand & Sons.
4) I. E. Freund and FJ William, Modern Business, Statistics.
5) A. M. Goon, M. K. Gupta and B. Das Gupta, Fundamentals of Statistics, Vol. I and II

Discipline Specific Elective-3 (Sem-VI)

Course Title: Data Mining
DSE-3 Course: V (Semester-VI)
Course Code: 2OUS6STDM5
Credits: O2 (36 lectures)

Course Objective: To learn to design and work efficiently with large data sets.
Course Outcome: By the end of this course, learner will able to:

- Work on Data sets
- Evaluate systematically supervised and unsupervised models
- Find predictive and descriptive techniques by using R software

Module	Title and content	No. Of lectures
1	**Learning Objective:** To introduce different data types and visualization techniques **Learning Outcomes:** At the end of the unit, learners will be able to • Learn to prepare data and classify according to attribute type • Understand different visualization techniques to represent data in a systematic way **Data Mining** a)Data preparation for knowledge discovery b)Data understanding c)Data Objects and Attribute Types, d)Data transformation e)Data Discretization: Discretization by Mining, Discretization by histogram analysis f)Data Visualization: Pixel orientation visualization technique, Geometric Projection Visualization Technique, Hierarchical Visualization Technique.	12L
2	**Learning Objective:** To learn different algorithms and analyze the data. **Learning Outcomes:** At the end of the unit, learners will be able to • Find Frequent item sets from given data • Clean the data by using R. **Application of Single Equation Technique** a) Data Processing ,Data Cleaning: missing Values, Noisy Data, b) Data Integration, Data Reduction : Principal component	12L

Analysis

c) Mining Frequent Patterns

d) Market Basket Analysis

e) Frequent item sets, Association

3 **Learning Objective:** To test the data and validate model

Learning Outcomes: At the end of the unit, learners will be able to

- Explain the concept of clustering
- Examine types of the data to be mined and present a general structure of classification

a) CRISP and SEEMA; Concept of training data, testing data and validation of model. **12L**

b) Supervised and unsupervised learning techniques: Problem of classification and Regression for predictive Analysis,

c) Classification techniques: k nearest neighbour

d) Naïve Bayes rule for two class problem with only one attribute variable cluster analysis using k-means with illustration for bivariate data.

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1. Breiman, L., Friedman, J.H., Olshen, R.A. and Stone, C.J. (1984). Classification and Regression Trees.(Wadsworth and Brooks/Cole).
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3. Galit Shmueli, Nitin Patel, Peter Bruce, (2010). Data Mining for Business Intelligence: Concepts, Techniques, and Applications in Microsoft Office Excel with XLMiner , Wiley
4. Hastie T., Tibshirani R. and Friedman J. H., (2003). The Elements of Statistical Learning: Data Mining, Inference and Prediction. Springer
5. Mitchell Tom, (1997). Machine Learning McGraw-Hill

Course Title: Biostatistics **DSE-3 Course: V (Semester-VI)**
Course Code: 2OUS6STBIO5 **Credits:** O2 (36 lectures)

Course Objective: To introduce students to applications of statistics in the field of medical sciences

Course Outcome: By the end of this course, learner will able to

- The rate at which infection spreads for a given epidemic.
- Evaluate statistically the significance of the treatments given.
- Formulate appropriate study design to estimate different parameters and analyse the results.

Module	Title and content	No. Of lectures
I	**Learning Objective:** To illustrate different deterministic and probabilistic models for estimating susceptibles and infectives in a given population. **Learning Outcomes:** At the end of the unit, learners will be able to • Define the terms involved in epidemics. • Explain the stages of epidemics. • Differentiate between deterministic and probabilistic models. • Compute the no. of susceptibles and infectives in case of deterministic models. • Estimate the probability of infectives in case of probabilistic models. **Epidemic Models** **a)** The features of Epidemic spread. Definitions of various terms involved. Simple mathematical models for epidemics: Deterministic model without removals, Carrier model, host-vector model, threshold value for population sizes. **b)** Chain binomial models. Reed - Frost and Greenwood models. Distribution of individual chains and total number of cases. Maximum likelihood estimator of 'p' using method of scores and its asymptotic variance for households of sizes up to 4.	IIL
2	**Learning Objective:** To enable learners to analyse the usefulness of drugs based on the response of the subjects. **Learning Outcomes:** At the end of the unit, learners will be able to • Define and differentiate terms involved in bio-assay	

- Differentiate between qualitative & quantitative assay
- Evaluate & Compare the potency of different drugs.
- Recommend the appropriate method of analyzing the potency.

Bioassays **7L**

a) Meaning and scope of bioassays. Relative potency. Directassays. Fieller's theorem.

b) Quantal Response assays. Tolerance distribution. Median effective dose ED50 and LD50 using Probit analysis and logit analysis

c) Indirect assays. Dose-response relationship .Condition of similarity and Monotony. Linearizing transformations. Parallel line assays & Slope Ratio assay(Concept Only).

3 **Learning Objective:** To explain the theory of clinical trials and methods to prove bio-equivalence.

Learning Outcomes: At the end of the unit, learners will be able to

- Illustrate different stages of clinical trials
- Devise proper questionnaire and estimate the required sample size
- Recommend appropriate study design.
- Assess the effectiveness of treatments.
- Estimate the different PK parameters.
- Analyze whether the drug is bio-equivalent.

a) Introduction to clinical trials: The need and ethics of clinical trials. Common terminology used in clinical trials. Over view of phases (I-IV). Study Protocol, Case record/Report form, Blinding (Single/Double) Randomized controlled (Placebo /Active controlled), Study Designs (Parallel, Cross Over). **18L**

b) Types of Trials: Inferiority, Superiority and Equivalence, Multicentric Trial. Inclusion/Exclusion Criteria. Statistical tools: Analysis of parallel Design using Analysis of Variance.

c) Concept of odds ratio. Sample size estimation.

d) Definitions of Generic Drug product. Bioavailability, Bioequivalence, Pharmako kinetic (PK) parameters Cmax, AUCt, AUCO-_, Tmax, Kel, Thalf. Estimation of PK parameters using 'time vs. concentration' profiles.

e) Analysis of Parallel design using logarithmic transformation (Summary statistics, ANOVA and 90% confidence interval).

f) Confidence Interval approach to establish bioequivalence (80/125 rule).

References:

1) Bailey N.T.J.: The Mathematical theory of infectious diseases, Second edition, Charles Griffin and Co. London.
2) Das M.N and Giri N.C. : Design and Analysis of Experiments, Second edition, Wiley Eastern
3) Finney D.J. : Statistical Methods in Biological Assays, First edition, Charles Griffin and Co. London
4) Sanford Boltan and Charles Bon: Pharmaceutical Statistics, Fourth edition, Marcel Dekker Inc.
5) Zar Jerrold H.: Biostatistical Analysis, Fourth edition, Pearson's education.
6) Daniel W.D. Biostatistics
7) Friedman L. M., Furburg C., Demets D. L. (1998): Fundamentals of Clinical Trials, First edition, Springer Verlag.
8) Fleiss J. L. (1989). The Design and Analysis of Clinical Experiments, Second edition, Wiley and Sons
9) Shein-Chung-Chow: Design and Analysis of Bioavailability & Bioequivalence studies, Third Edition, Chapman & Hall/CRC Biostatistics series.

Discipline Specific Elective-4 (Semester - VI)

Course Title: Time Series **DSE-4 Course: VI (Semester – VI)**
Course Code: 2OUS6STTS6 **Credits:** O2 (36 lectures)

Course Objective: To introduce students to applications of time series in forecasting using statistical methods.

Course Outcome: By the end of this course, learner will able to

- Distinguish different components of time series.
- Estimate future values of a time series.

Module	Title and content	No. Of lectures
1	**Learning Objective:** To state different component of time series **Learning Outcomes:** At the end of the unit, learners will be able to • Determine trend values by different methods • Estimate seasonal component by different methods **Introduction and decomposition of times series:** a) application of time series, Components of a times series, Decomposition of time series. b) Estimation of trend by free hand curve method, method of semi averages, fitting mathematical curve and growth curves. c) Estimation of trend by method of moving averages. d) Estimation of seasonal component by the methods of - simple averages, Ratio to Trend, Ratio to Moving Averages and Link Relative method. Deseasonalization. e) Cyclic Component: Harmonic Analysis.	15L
2	**Learning Objective:** To enable learners to analyse moving average and autoregressive processes. **Learning Outcomes:** At the end of the unit, learners will be able to • Estimate parameters of different processes • Define autocorrelation functions of different processes. **Autocorrelation functions and Autoregressive processes:** a) Random Component: Variate difference method. Stationary Time series: Weak stationarity,	7L

b) Autocorrelation function and the correlogram. Moving-average MA) process and Autoregressive (AR) processes.

c) Estimation of the parameters of AR(1) and AR(2). Autocorrelation functions of AR(1) and AR(2) processes.

3 **Learning Objective:** To explain different methods of forecasting.

Learning Outcomes: At the end of the unit, learners will be able to

- Estimate future values of time series by exponential smoothing
- Compare values by different methods of forecasting

Forecasting: **14L**

a) Forecasting by the methods of Exponential smoothing.

b) Introduction to ARMA and ARIMA models. Short-term forecasting methods, Brown's discounted regression, Box-Jenkins method and Bayesian forecasting.

References:

1. Montgomery, D. C. and Johnson, L. A. (1967). Forecasting and Time Series Analysis, IstEd. McGraw-Hill, New York.
2. Gupta, S.C. and Kapoor, V.K. (2014). Fundamentals of Mathematical Statistics, 11th Ed., Sultan Chand and Sons.
3. Kendall, M.G. (1976). Time Series, 2nd Ed., Charles Griffin and Co Ltd., London and High Wycombe.

Course Title: Linear Models **DSE-4 Course:** VI (Semester – VI)
Course Code: 2OUS6STLM6 **Credits:** 02 (36 lectures)

Course Objective: To introduce students to linear models with the help of matrix theory.

Course Outcome: By the end of this course, learner will able to

- Do basic operations on matrices.
- Construct appropriate linear models and test the hypothesis of the parameters.
- Analyse a Co-variance matrix.

Module	Title and content	No. Of lectures
1	**Learning Objectives:** To revise matrix theory **Learning Outcomes:** At the end of the unit, learners will be able to • Calculate the inverse & generalized inverse of a matrix. • Re-write the matrix in canonical forms. • Specify the eigen values & eigenvectors of a matrix. **Pre-requisites** a) Basic operations, determinants, inverse and rank of a matrix, canonical forms. b) Solving linear equations, generalized inverse. c) Partitioned matrices, its determinant and inverse. d) Eigen values and Eigenvectors of a matrix. e) Vector spaces.	18L
2	**Learning Objectives:** Help formulate the general linear model and check its adequacy. **Learning Outcomes:** At the end of the unit, learners will be able to • Construct appropriate general linear model • Calculate interval for estimates of the parameters. • Test relevant hypothesis of the parameters. **The General Linear Model** a) Linear parametric function and its estimability. b) Gauss-Markoff theorem. c) Interval estimates and test of hypothesis. d) Fundamental theorems on conditional error s.s. e) Test of $\Lambda\beta=d$.	11L

3 **Learning Objectives:** To analyse general linear model when observations are correlated.

Learning Outcomes: At the end of the unit, learners will be able to

- Analyse a covariance matrix in case of one-way & two-way classification.

Analysis of Covariance(ANOCOVA) **7L**

a)Introduction

b) Analysis of Covariance

c) Analysis of Covariance of a Two-Way Classification

References:

1. Hohn Franz E: Elementary Matrix Algebra
2. Searle S.R.: Matrix Algebra useful for Statistics
3. Kshirsagar A.M.: A course in Linear Models
4. Draper N.R & Smith H: Applied Regression Analysis.
5. Song GUI Wang and S.C Chow: Advanced Linear Models.

Skill enhancement course (Semester -VI)

Course Title: Statistical Computing using R
Course: VII (Semester – VI)
Course Code: 2OUS6STSCR7
Credits: 02 (36 lectures)

Course Objective: To develop simple R- programs
Course Outcome: By the end of this course, learner will able to

- Write Simple R-commands to calculate various statistical measures
- Write R-commands for testing of hypothesis and ANOVA

Module	Title and content	No. Of lectures
I	**Learning Objective**: To acquire knowledge about various R commands and functions for statistical computing **Learning Outcome**: By the end of this unit, learner will able to • Construct various methods of inputting data • State various built-in functions • Provide accurate graphs and diagrams • Construct R-commands for computing various statistical constants • Construct R-commands for various discrete probability distributions **Introduction to R software, Descriptive statistics and discrete probability distributions** **a)** Introduction to R as a statistical software and language, R as a calculator, R preliminaries, Saving Storing and Retrieving work **b)** Methods of data input: c function, Sequence operator and seq function, scan function, rep function, data.frame function, matrix function, class function, Importing data from Excel. **c)** Built-in functions: length(), max(), min(), range(), sum(), cumsum(), mean(), median(), var(), sort() **d)** Diagrammatic and Graphical representation of data, **e)** Descriptive Statistics using R software: Frequency table (univariate and bivariate),Measures of central tendency, dispersion, moments, skewness and kurtosis, Correlation and regression analysis **f)** Discrete probability distributions: Binomial, Poisson, Hypergeometric	18L

2 **Learning Objective**: To write simple R-programs

Learning Outcome: By the end of this unit, learner will able to

- Construct R-commands for various continuous probability distributions
- Construct R-commands for various methods of sampling
- Develop R-commands for computing p-values required in study of estimation and testing of hypothesis
- Solve analysis of one-way and two-way classification using R
- Write simple R-programs

Continuous probability distributions, Sampling, Testing of hypothesis, Analysis of variance, R-programming 18L

a) Continuous probability distributions: Normal distribution, t-distribution, chi-square distribution, exponential distribution

b) Sampling methods: SRSWR, SRSWOR, stratified random sampling, systematic sampling

c) Testing of hypothesis: Normality check, Parametric and non-parametric

d) Analysis of variance: One way classification, Two way classification

e) R as a programming language: Grouping, loops and conditional execution, Functions