Shaheed Benazir Bhutto Women University
Peshawar

Department of Statistics

Curriculum of BS, M.Phil and PhD in Statistics
2019-Onwards

BS (4 YEARS) STATISTICS

PROGRAM OBJECTIVES

- To provide students with sound background of statistical knowledge and skills, so that they can pursue higher degrees and research in the field of statistics. And to compete in the job market.
- To prepare the students to provide help and consultation in data analysis to researchers, working in various fields.
- To enable the students to link theory with practice while using Statistical techniques and to highlight the role of Statistics and its importance in Research.
- To enable the students to implement statistical packages for data analysis and research.
- To involve the students in project based activities.

INTENDED OUTCOMES OF THE PROGRAM

Upon successfully completing the study program the students will be able to:

- Apply statistical techniques to solve the survey and research problems in various areas.
- Analyze and interpret the data in conducting researches
- Communicate effectively the results with researchers in their professional dealings.
- Work as a part of organization and take optimal decisions in improving the productivity and utilization of the resources of the organization.
- Demonstrate best standards of professional and ethical practices and responsibilities.

Details of the Program

Title of the Program	BS Statistics
Duration of the Program	4 years, comprises of 8 Semesters
Total No. of Credit Hours	124-140
Semester Duration	16 weeks of Teaching (Excluding Examinations)
Course Load Per Semester	15-18 Credit Hours

Courses Layout

Categories	No of Courses Min-Max	Credit Hours Min-Max
Compulsory Requirement	9	25
General Courses **(to be chosen from other departments)**	7-8	21-24
Foundation Courses **(Discipline Specific)**	9-10	30-33
Major Courses	11-13	36-46
Elective Courses	4	12
Total		**124-140**

SCHEME OF STUDIES FOR BS (4-YEAR)

Year	Course Code	Course Title	Credit Hours
1st Year		**SEMESTER 1**	
	STAT-306	Introduction to Statistics	3
	MTH-303	Basic Mathematics	3
	CSC-301	Introduction to Information and Communication Technologies	3
	ENG-301	English-I	3
	ISl-320	Islamic Studies	2
		General-I	3
		Total	**17**
		SEMESTER 2	
	STAT-307	Fundamentals of Probability and Probability Distributions	3
	MTH-307	Basic Calculus	3
	ENG-302	English-II	3
	PST-323	Pakistan Studies	2
		General-II	3
		General-III	3
		Total	**17**
2nd Year		**SEMESTER 3**	
	STAT-405	Exploratory Data Analysis and Visualization	3
	STAT-406	Basic Statistical Inference	3
	MTH-305	Mathematics-II	3
	CSC-302	Programming Fundamentals	3
	ENG-410	English-III	3
		General-IV	3
		Total	**18**
		SEMESTER 4	
	STAT-407	Introduction to Regression and Analysis of Variance	3
	STAT-408	Statistical Packages	3
	STAT-409	Linear Algebra	3
		General-V	3
		General-VI	3
		Total	**15**
3rd Year		**SEMESTER 5**	
	STAT-511	Random Variables and Probability Distributions	3
	STAT-512	Sampling Fundamentals and Techniques	3
	STAT-513	Experimental Designs	3
	STAT-514	Regression Analysis	3
	STAT-506	Nonparametric Methods	3
		Total	**15**
		SEMESTER 6	
	STAT-521	Continuous Probability Distributions	3
	STAT-522	Sampling Techniques and Survey Methods	3
	STAT-523	Experimental Designs and Analysis of Experiments	3
	STAT-524	Econometrics	3
	STAT-507	Population Studies	3
		Total	**15**
4th Year		**SEMESTER 7**	
	STAT-611	Statistical Inference : Estimation of Parameters	3
	STAT-612	Multivariate Methods	3
	STAT-606	Survey and Research Methods	3
	STAT-	Elective-I	3
	STAT-	Elective-II	3
		Total	**15**
		SEMESTER 8	
	STAT-621	Statistical Inference: Hypothesis Testing	3
	STAT-622	Applied Multivariate Analysis	3
	STAT-699	*Project/Internship/ Optional subjects	6
	STAT-	Elective-III	3
	STAT-	Elective-IV	3
		Total	**18**
		Total	**130**

* The Students have to complete a project or internship with an optional course or two optional courses.

LIST OF GENERAL COURSES FOR STATISTICS

Seven-eight courses are to be selected from the following list of courses, according to available facilities and faculty of the universities.

S.N	Course Codes	Course Title	Credit Hours
1.	ECO-01	Principles of Micro Economics	3
2.	ECO-02	Principles of Macro Economics	3
3.	ECO-03	Managerial Economics	3
4.	ECO-04	Fundamentals of Economics	3
5.	ECO-05	Economy of Pakistan	3
6.	MTH-303	Basic Mathematics	3
7.	MTH-304	Mathematics-I	3
8.	MTH-305	Mathematics-II	3
9.	MTH-307	Basic Calculus	3
10.	MTH-312	Fundamentals of Mathematics	3
11.	MTH-313	Advanced Calculus	3
12.	MTH-402	Analytical Geometry	3
13.	MTH-403	Numerical Computing	3
14.	MTH-407	Differential Equations	3
15.	MTH-409	Mathematical Modeling	3
16.	CSC-302	Programming Fundamentals	3
17.	MS-304	Introduction to Management	3
18.	MS-401	Introduction to Human Resource Management	3
19.	MS-412	Marketing Management	3
20.	MS-512	Financial Management	3
21.	MS-612	Business Administration (Entrepreneurship)	3
22.	BI-402	Bioinformatics and Statistical Genetics	3
23.	ZOL-401	Essentials of Biology	3
24.	PHY-301	Mechanics-I	3
25.	PHY-302	Mechanics-II	3
26.	PHY-305	Introductory Electricity & Magnetism	3
27.	PSC-401	Basic Concepts in Political Science	3
28.	PSC-402	Basic Concepts in International Relations	3
29	PSY-301	Understanding Psychology	3
		Environmental Sciences	3
		History of Human Civilization	
		*Foreign Language other than English	

or any other subject depending upon the expertise available.

List of Elective Courses (offered in 7th and 8th semester**)**

S.No	Course Code	Course Title	Credit Hours
1	STAT-613	Statistical Quality Control	3
2	STAT-614	Applied Statistics	3
3	STAT-615	Robust Methods	3
4	STAT-616	Operation Research	3
	STAT-617	Statistical Practicum	
5	STAT-618	Bio statistical Analysis	3
7	STAT-619	Official Statistics	3
8	STAT-620	Categorical Data Analysis	3
9	STAT-623	Stochastic Process	3
10	STAT-624	Time Series Analysis	3
11	STAT-625	Decision Theory	3
12	STAT-626	Reliability Analysis	3
13	STAT-627	Survival Analysis	3
14	STAT-628	Data Mining	3
15	STAT-629	Actuarial Statistics	3
16	STAT-630	Mathematical Modeling & Simulation	3
17	STAT-631	Bayesian Analysis	

DETAILS OF THE COURSES

STAT-306 Introduction to Statistics (3 Cr.Hrs)

Learning Objectives:

- To have introduction of statistics as a field of knowledge and its scope and relevance to other disciplines of natural and social sciences.
- To equipped and prepare students for advance courses in the field of statistics.
- To achieve the capability of critical thinking about data and its sources; have idea about variables and their types and scale measures.
- Be able to calculate and interpret descriptive statistics (able to classify, tabulate, describe and display data using software).

Learning Outcomes:

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

- Organize and display the data through tables and graphs.
- Understand and differentiate between the types of data and variables.
- Evaluate and Interpret basic descriptive statistics.

Course Contents:

The nature and scope of the Statistics. Organizing of Data, classification of data, Graphs and Charts: Stem-and leaf diagram, Box and Whisker plots and their interpretation. Measures of Central Tendency and Dispersion: Their properties, usage, limitations and comparison. Calculations for the ungrouped and grouped data. Measures of Skewness and Kurtosis and Distribution shapes. Probability Concepts, Addition and Multiplication rules, bivariate frequency tables, joint and marginal probabilities, Conditional probability and independence, Bayes' rule.

Books Recommended:

1. Chaudhry, S.M.and Kamal, S. (1996), "Introduction to Statistical Theory" Parts I & II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.
2. Chaudhry, S.M.and Kamal, S. (1996), "Introduction to Statistical Theory" Parts I & II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.
3. Clark, G.M and Cooke, D. (1998), "A Basic Course in Statistics" 4th ed, Arnold, London.
4. Mclave, J.T., Benson, P.G. and Snitch, T. (2005) "Statistics for Business & Economics" 9th ed.Prentice Hall, New Jersey.
5. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "Probability and Statistics", 2nd ed. Schaums Outlines Series. McGraw Hill. NY.
6. Walpole, R.E., Myers, R.H and Myers, S.L. (1998), "Probability and Statistics for Engineers and Scientist" 6th edition, Prentice Hall, NY.
7. Weiss, N,A.(1997), "Introductory Statistics" 4th ed. Addison-Wesley Pub. Company, Inc.

STAT-307 Fundamentals of Probability and Probability Distributions (3 Cr.Hrs)

Learning Objectives:

- Understand basic concepts of probability, conditional probability, independence etc.
- Be familiar with some of the more commonly encountered random variables, particularly the Binomial and Normal random variable.
- Be able to calculate first two moments of common random variables i.e. means and variances.
- Be able to apply the concepts of random variables to scientific applications. Computation of uncertainty using probability techniques.

Learning Outcomes:

At the end of the course the students will be able to:

- Demonstrate the basic knowledge of probability and probability distribution.
- Explain the concepts of basic techniques of measuring the uncertainty problem.
- Analyse and apply probability techniques.

Course Contents:

Discrete Random Variables, Probability Distribution, Mean and Variance of a discrete random variable Bernaulli trials. Properties, applications and fitting of Binomial, Poisson, Hyper geometric. Negative Binomial and Geometric distributions. Continuous Random Variable, probability density function and its properties. Normal Distribution and its properties, Standard Normal Curve, Normal approximation to Binomial and Poisson distributions.

Books Recommended

1. Clark, G.M. and Cooke, D. (1998), "A Basic Course in Statistics" 4th ed, Arnold, London.
2. Chaudhry. S.M.and Kamal, S. (1996), "Introduction to Statistical Theory" Parts I & II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.
3. Mclave, J.T., Benson, P.G. and Snitch, T. (2005) "Statistics for Business & Economics" 9t ed, Prentice Hall, New Jersey.
4. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "Probability and Statistics", 2nd ed. Schaums Outlines Series. McGraw Hill. NY.
5. Walpole, RE., Myers, R.H and Myers, S.L. (1998), 'Probability and Statistics for Engineers and Scientist" 6th edition, Prentice Hall, NY.
6. Weiss, N.A.(1997), "Introductory Statistics" 4th ed. Addison-Wesley Pub. Company, Inc.

STAT-405 Exploratory Data Analysis and Visualization (EDAV) (3 Cr.Hrs)

Learning Objectives:

- to provide solid understanding of the process of Exploratory Data Analysis
- to educate students in data exploration, analysis, and visualization
- to train students in industry standard tools for data analysis and visualization

Learning outcomes:

Upon completion of this course the students will be able to**:**

- describe exploratory data analysis and visualization concepts
- describe data analysis and visualization models and algorithms
- describe applicability of different data analysis and visualization models techniques to solve real-world problems
- pre-process data and apply exploratory data analysis to some real data sets and provide interpretations via relevant visualization

Course Contents:
Exploratory Data Analysis: Explore, Visualize, Analyze, Repeat. Selective data collective and data exploration. Principles of Analytic Graphics, Exploratory Graphs, The base plotting system. The ggplot2 plotting systemData visualization and Data analysis (using Excel/Tableau/R/STATA/SPSS etc).

Recommended Books:

1. Peng R. (2015) Exploratory Data Analysis with R http://leanpub.com/exdata
2. Tukey, J. (1977) Exploratory Data Analysis
3. Chang, W. (2013). R Graphics Cookbook. O'Reilly. http://www.cookbook-r.com/
1. Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis (2nd edition Springer. http://ggplot2.org/book/; http://hadley.nz/

STAT- 406 Basic Statistical Inference (3 Cr.Hrs)

Learning Objectives:
- To understanding of basic techniques of sampling and estimation, their properties and application
- To select a sample from a given population and use it to make inferences about the population and its parameter
- To test, deduce and infer the validity of different types of hypotheses and models built on the basis of the raw data collected in diverse problem-situations.

Learning Outcomes:
After this course the students will be able to:
- The knowledge of the sampling distributions and their properties.
- Derive the appropriate estimators for parameters using best estimation procedure.
- Use appropriate sampling distributions for interval estimation and hypotheses testing.
- Apply appropriate inferential procedures to handle the practical situations.

Course Contents:

Distribution of sample mean and central limit theorem. Estimation: Point Estimation. Desirable Properties of a Good Estimator. Interval Estimation. lnterval Estimation of population mean. Large and small sample confidence intervals for Population Mean. Nature of Hypothesis Testing and Types of errors. Hypothesis Testing for Population Mean and variance. Inferences for Two Population Means. Large-sample inferences for Two Populations using Independent Samples. Inferences for the Mean of Two Normal Populations using Independent Samples (variances are assumed Equal/Not Equal). Inference for Two Populations Mean using Paired Samples.

Inferences for Population Proportions. Confidence Intervals and hypothesis Testing for Population Proportion. Inferences for Two Populations Proportions using independent Samples, Estimation of sample size. Chi-Square Procedure. Chi-Square Goodness-of fit Test. Chi-Square Independence Tests.

Pre-Requisite: STAT- 306

Books Recommended:

1. Clark, G.M. and Cooke, D. (1998). A Basic Course in Statistics. 4th ed, Arnold, London.
2. DeGroot, M. Schervish, M. (2017). Probability and Statistics. 4th edition. Pearson Education Limited.
3. Mclave, J.T., Benson P.G. and Sincich, T. (2014). Statistics for Business and Economics. 12th Edition. Pearson Education Ltd, U.K.
4. Ross, S. (2017). A first course in Probability. 9th edition. Pearson Education Limited.
5. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2015). Probability and Statistics. 3rd edition. Schaums Outlines Series. McGraw-Hill. NY.
6. Srivastava, M.K., Khan, A.H. and Srivastava, N. (2014). Statistical Inference: Theory of Estimation. Prentice-Hall of India Pvt. Ltd
7. Walpole, RE., Myers, R.H. and Myers, S.L. (1998), "Probability and Statistics for Engineers and Scientist" 6th edition, Prentice Hall, NY.

STAT-407 Introduction to Regression and Analysis of Variance (3 Cr.Hrs)

Course Objectives:

- To provide foundations of regression analysis and experimental designs and their uses in different disciplines.
- To provide basic knowledge and art of statistical data analysis and planning and designing of experiments.
- To enable the students to predict and draw inference about the parameters of the population.

Learning Outcomes:

At the end of the course the students will be able to:

- Explore more adequately the connection between theories of regression and understand the basic concepts and applications of experimental design
- Perform analysis of real world problems and Decide appropriate design for given scenario.
- Provide prediction of dependent variable and interpret the results.

Course Contents:

Concepts of Regression and Correlation, Simple linear regression model, Estimation of parameters by method of least squares and corresponding variance estimates, Testing and confidence intervals for least squares estimators, mean prediction and individual prediction. Multiple linear regression with two regressors, coefficient of multiple determination, Partial and multiple correlation up to three variables. Inference of simple, partial and multiple correlation coefficients, Analysis of variance for one-way classification and two-way classification. Decomposition of total sum of squares, Multiple comparison tests; least significant difference and Duncans multiple range test, Tukey test and Least significant difference test.

Pre-Requisite: STAT-306

Books Recommended

1. Clark, G. M. and Kempson, R. E. (1997), "Introduction to the Design & Analysis of Experiment" Arnold London.
2. Chaudhry, S.M., and Kamal, S., (1996), "Introduction to Statistical Theory" Part I, II, 6th ed, Ilmi Kitan Khana, Lahore, Pakistan.
1. Montgomery, D.C. (2012). Design and Analysis of Experiments, John Wiley & Sons, New York, USA.
2. Oehlert, G.W. (2000). A first course in design and analysis of experiments, W.H. Freeman, New York, USA.
3. Steel, R.G.D, Torrie , J.H. and Dickey D.A. (2008). Principles and Procedures of Statistics: A Biometrical Approach. McGraw-Hill, Michigan, USA.
4. Walpole, P.E., Myers R.H., Myers S.L. (1998), "Probability and Statistics for Engineers and Scientists", 7th ed.Prentice Hall.
5. Weiss, N.A, (1997), "Introductory Statistics" 4th ed. Addison-Wesley Pub.Company, Inc.

STAT-408 Statistical Packages (3Cr.Hrs.)

Course Objectives:

- To understand basics of data analysis through SPSS and R.
- To learn visualization of data through Minitab, SPSS and R.
- To learn basic programming in R.

Learning Outcomes:

At the end of the course the students will be able to:

- Understand the data presentation and analysis using Minitab and SPSS.
- Learn basic programming in R for statistical data analysis.
- Describe concepts as they are implemented in real world data.

Course Contents:

Introduction to statistical packages and programming languages, Introduction to Minitab, data manipulation, graphical representation, qualitative and quantitative data analysis and programming. Introduction to SPSS, data manipulation, descriptive statistics, function related to probability distributions, SPSS modules, graphical representation of data, tabulation and transformation of variables.

Introduction to R, language essentials; expression and objects, functions and arguments, vectors, missing values, matrices and arrays, factors, data frames, indexing, conditional selection, indexing of data frames, sorting, Data entry; reading from text files, the data editor, interfacing to other programs. Descriptive statistics and graphics.

Note: Use of any other statistical package based upon the availability of the Software.

Books Recommended:

1. Crawley, M. J. (2012). The R book. John Wiley & Sons.
2. Delwiche, Lora D. and Slaughter Susan J. (1998) The Little SAS Book A Primer, Seco.c Edton, SAS institute, North Carolina.

3. Marques do Sd, Joaquim P.(2003) Applied Statistics using SPSS, STATISTICA and MATLAB
4. Norusis. Marija (2006) SPSS 14.0 Guide to Data Analysis, Prentice Hall, New Jersey.
5. Pace, L. (2012). Beginning R: An introduction to statistical programming. Apress.
6. Ryan, Barbara F.: Joiner, Brian L. and Cryer, Jonathan D.(2005) MINITAB Handbook, 5th Edition, Duxbury Press, California.
7. SPSS (2006) SPSS 14.0 Base User's Guide, , Prentice Hall, New Jersey.
8. Zumel, N., & Mount, J. (2014). Practical data science with R. Manning Publications Co.

STAT-409 Linear Algebra (3Cr.Hrs.)

Course Objectives:

- To develop the ability to solve problems using the techniques of linear algebra
- To Understand Euclidean vector spaces, their inherent arithmetic and algebraic structure, and the accompanying geometry that arise
- Acquire facility working with general vector spaces, linear transformations, coordinate vectors, and the changing of bases.
- To analyse the structure of real-world problems and plan solution strategies. Solve the problems using appropriate tools.

Learning Outcomes:

At the end of this course the students will be able to:

- Interpret the Use of vector equations and linear transformations and its application in image processing and Control theory, etc
- Apply mathematical concepts in problem-solving through integration of new material and modelling
- Analyse/interpret quantitative data verbally, graphically, symbolically and numerically.

Course Contents:

Introduction to Vectors. Vector spaces and subspaces. Linear Equations: Introduction, Gaussian elimination and matrices, Gauss-Jordan method, Making Gaussian elimination work, Ill-conditioned systems. Echelon Forms: Row echelon form and rank, The reduced row echelon form, Consistency of linear systems, Homogeneous systems, Nonhomogeneous systems. Matrix Algebra: Addition, scalar multiplication and transposition, linearity, matrix multiplication, properties of matrix multiplication, matrix inversion, inverses of sums and sensitivity, elementary matrices and equivalence, The LU factorization. Vector spaces: spaces and subspaces, four fundamental subspaces, linear independence, basis and dimension, more about rank, classical least squares, linear transformations, change of basis and similarity, invariant subspaces. Norms, Inner products, and Orthogonality: Vector norms and inner products, orthogonal vectors, Gram-Schmidt procedure, Unitary and orthogonal matrices, orthogonal reduction, complementary subspaces, range-null space decomposition, orthogonal decomposition, singular value decomposition, orthogonal projection, angles between subspaces. Determinants and their properties. Eigenvalues and Eigenvectors.

Books Recommended

1. Anton, H. (2013). Elementary Linear Algebra, John Wisely publisher, 10th edition,
2. David C. L. (2014). Linear Algebra and its Applications, 5th edition.
3. Lay, D.C. (2006) "Linear Algebra and its applications" 3rd Edition, Addison-Wesely.
4. Leon, J. S. (2015). Linear Algebra with Applications, 9th edition.

5. Strang, G. (2009), "Introduction to Linear Algebra" 4th Edition, Wellesley-Cambridge Press.
6. Seymour, L and Marc, L. (2006), Linear Algebra, Schaum's Outline Series, McGraw-Hill.
7. Strang, G. (2016). Introduction to Linear Algrebra , 5th edition.

STAT-511 Random Variables and Probability Distributions (3 Cr.Hrs)

Course Objectives:

- This course is designed to give students a conceptual knowledge of discrete random variables and probability theory.
- This course provides the fundamentals of probability theory in different disciplines.
- This course helps to model the uncertain behavior from the real life scenario.

Learning Outcomes:

- Understand the basic concepts and applications of probability.
- Investigate the nature of stochastic process and apply suitable probability distributions for the random variable generated from such process.
- Find probabilities using probability distributions.
- Use probability concepts and laws in decision analysis.

Course Contents

Probability as a set function. Conditional probability and Bayes' theorem. Random variables, Distribution function, Probability mass function and probability density function. Location, scale, and shape parameters. Joint and conditional distributions for two and more random variables. Marginal and conditional distributions, stochastic independence. Mathematical expectation and its properties, Conditional expectation, variance and moments. Probability generating function. Moment generating and characteristic functions and their properties. Relation between moments and cummulants. Probability distributions: Bernoulli, Binomial, Hypergeometric, Poisson, Negative binomial, Geometric, discrete uniform, Multinomial distribution. Normal approximation to binomial, Poisson and Hypergeometric distribution.

Pre-Requisite: STAT-307

Books Recommended

1. Haq, M. (1984). Foundation of Probability and Statistics, Tahir sons, Urdu Bazar, Karachi
2. Hirai, A.S. (2002), A Course in Mathematical Statistics, Ilmi Katab Khana, Lahore.
3. Hogg, R.M., McKean, J. and Craig, A.T. (2013). Introduction to Mathematical Statistics. Prentice Hall, New Jersey, USA.
4. Khan, M. K., (1996). "Probability with Applications", Maktiba Ilmi, Lahore.
5. Mood, AM, Graybill, F.A. and Boss, D.C. (1997), "Introduction to the Theory of Statistics", McGraw Hill, New York.
6. Stirzaker, D. (1999). "Probability and Random Variables". Cambridge University Press, Cambridge.
7. Stuart, A. and Ord, J .K. Kendall's' (1998), "Advanced Theory of Statistics", Vol. I, Charles Griffin, London.
8.

STAT-512 Sampling Techniques-I (4 Cr. Hrs) (3+1)

Course Objectives:

- To introduce the concept and scope of sampling.
- To determine the sample size for conducting a survey.
- To learn ratio and regression estimations.
- To understand the concept of simple and stratified random sampling techniques.

Learning Outcomes:

At the end of the course the students will be able to:

- Use and implement of sampling designs.
- Apply the simple random sampling and the stratified random sampling appropriately in real world problems.
- Estimate the population parameters by using simple and stratified random sampling techniques.

Course Contents:

Introduction to Sampling, advantages of sampling, requirements of a good sample, bias, sampling and non-sampling errors, Steps and problems involved in planning and conduct of census and their sources, sample surveys, Selection and estimation procedures. Description and properties of simple random sampling, Sampling for proportions and percentages, Estimation of variances, standard errors and confidence limits, Sample size determination under different conditions, Description and properties of stratified random sampling, Formation of strata, Different methods of allocation of sample size, Ratio and regression estimates in simple and stratified random sampling

Note: Practicals of this course shall include visits of the students to various national statistical organizations and a report submitted to this effect.

Books Recommended

1. Bethelem, J. (2009). Applied Survey Methods: A Statistical Perspective. Wiley.
2. Cochran, W.G. (1977), "Sampling Techniques' 3rd ed, John Wiley and Sons, New York.
3. Ferguson, T.S. (1996), "A Course in large Sample theory, Chapman & Hall, London.
4. Kish, L. (1992). "Survey Sampling", John Wiley, New York.
5. Raj, D. (1971) "Design of Sample Survey". McGraw Hill, New York.
6. Raj, D. & Chandhok, P. (1998), "Sample Survey Theory". Narosa Publishing House, New Delhi.
7. Singh, R. and Singh N, (1996), "Elements of Survey Sampling", Kuiwar Academic Publisher, Dodrecht.
8. Sukhatme, P.V, Sukhatme, B., Sukhatme, S., and Asok, A. (1985), "Sampling Theory of Survey with Application". Iowa State University Press.

STAT-513 Experimental Designs (4 Cr.Hrs)

Course Objectives:

- This course provides the fundamentals of experimental designs and their uses in different disciplines.
- To provide basic and advanced learning of investigation for conclusions through planning and designing of experiments.

- To train students through innovative instruction in design theory and methodology that will help them in addressing the significance of experimental design in statistics and across the universal disciplines.

Learning Outcomes:
This course will enable the students to:

- Understand the basic concepts and applications of experimental design.
- Decide an appropriate design for a given scenario.
- Analyse the data generated from different designs and interpret the results.

Course Contents:

Introduction to experimental design and its terminology; Planning and designing of experiment and research; Aspects of experimental design, basic principles of experimental design, fixed and random effects. Analysis of variance, estimation of model parameters. Checking model adequacy, Inference beyond ANOVA multiple comparisons, Contrast analysis, orthogonal polynomial contrasts and trend analysis. Basic experimental designs; completely randomized design, randomized complete block design and Latin square design. Relative efficiency of these designs. Missing values, Incomplete block designs (IBD), balanced incomplete block designs (BIBD) and partially balanced incomplete block designs (PBIBD). Intra-block and Inter-block analysis of IBD.

Books Recommended:

1. Boniface, DR. (1995). "Experiment Design & Statistical Methods", Chapman & Hall.
2. Clarke, G.M., and Kempton, RE. (1997), "Introduction to the Design & Analysis of Experiments", Edward Arnold.
3. Kehul, R.O. (2000). Design of Experiments: Statistical Principles of Research Design and Analysis, Duxbury/ Thomson Learning, New York, USA.
4. Montgomery, D.C. (2000). "Design and Analysis of Experiments", John Wiley, New York.
5. Montgomery, D.C. (2012). Design and Analysis of Experiments, John Wiley & Sons, New York, USA.
6. Oehlert, G.W. (2000). A first course in design and analysis of experiments, W.H. Freeman, New York, USA.

STAT-514 Regression Analysis (4 Cr.Hrs)

Course Objectives:

- To understand the basic assumptions of regression analysis.
- To handle the problems arising from the violation of assumptions.
- To understand the estimation techniques of parameters.
- To give the concept of nonlinear regression analysis.

Learning Outcomes:
At the end of the course:

- Students would have enough knowledge of regression analysis.
- Students will be able to understand the concept of basic
- Students will know the assumption of regression.
- Developed the skills of students to analyse the real phenomena of regression models.

Course Contents:

Linear regression and its assumptions, Least squares estimators, Maximum Likelihood Estimator, tests of significance for regression model and regression parameters. Confidence interval for regression parameters, Test of linearity of regression, Use of extraneous information in linear regression model. Residual analysis, Detection and study of outliers and influential observations, Polynomial regression, orthogonal polynomial, orthogonal regression analysis and Specification of models.

Pre-Requisite: STAT-406

Books Recommended:

1. Dielman, T. E. (2001). Applied regression analysis for business and economics. Pacific Grove, CA: Duxbury Thomson Learning.
2. Guttmann, I, (1980); "Linear Models: An Introduction", John Wiley, New York.
3. Montgomery, D. C., Peck, E. A., & Vining, G. G. (2012). Introduction to linear regression analysis (Vol. 821). John Wiley and Sons.
4. Montgomery, D.C., and Peck E.A. (1992). "lntroduction to linear Regression Analysis", 2nd Edition, John Wiley and sons Inc. New York.
5. Rawlings, J. O., Pantula, S. G., and Dickey, D. A. (2001). Applied regression analysis: a research tool. Springer Science & Business Media.
6. Ryan, P. T. (1996) "Modern Regression Methods", John Wiley and sons Inc. New York.
7. Yan, X. and Zu, X. G. (2009) Linear Regression Analysis: Theory and Computing. World Scientific Publications.

STAT-506 Non-Parametric Methods (3 Cr.Hrs.)

Course Objectives:

- The course is designed to give students knowledge about the basic concepts of nonparametric methods.
- This course provides the fundamentals of different non-parametric methods.
- This course helps in understanding of applications of non-parametric methods.

Learning Outcomes:

At the end of the course the students:

- Will have knowledge of elementary non-parametric methods.
- They will be able to use these nonparametric procedures for analyzing real data.
- Will know application of an appropriate nonparametric test for a specific scenario.

Course Contents:

Rationale of non-parametric methods, Chi-Square Procedures: Chi-Square Goodness of fit Test, Chi-Square test of independence, Location estimates for single sample: The sign test, modified sign test, Wilcoxon signed rank test, confidence interval based on these tests. Runs test for randomness. Anderson-Darling test. Distribution tests and rank transformation, Kolmogrov's

test, Lilliefor's test and Shapiro-Wilks test for normality. Tests and estimation for two independent samples; the median test, Wilcoxon Mann – Whitney test. The Siegel – Tukey test, the squared rank test for variance, Smirnov test, Tests for paired samples, Kruskal – Wallis test, Friedman test, multiple comparison with the Friedman test, Cochran's test for binary responses Spearman's rank correlation coefficient, Kendall's rank correlation coefficient. Theil's regression method.

Books Recommended:

1. Conover, W.J. (1999), "Practical Nonparametric Statistics", 3rd Edition, John Wiley and Sons, New York.
2. Gibbons, J.D. and Chakraborti, S. (1992), "Nonparametric Statistical Inference", Marcel Decker, New York.
3. Maritz, J.S. (1995). "Distribution-Free Statistical Methods". Chapman & Hall London.
4. Sprint, P. (2007). Applied Nonparametric Statistical Methods, 4th edition, Chapman & Hall London
5. Sprint, P. (1989). "Applied Nonparametric Statistical Methods". Chapman & Hall London.

STAT-521 Continuous Probability Distributions (3 Cr.Hrs.)

Course Objectives:

- This course is designed to give students a conceptual knowledge of continuous random variables and probability theory.
- This course provides the fundamentals of probability theory in different disciplines.
- This course helps to model the uncertain behavior from the real life scenario.

Learning Outcomes:

At the end of the course the students will be able to:

- Understand the basic concepts and applications of probability.
- Investigate the nature of stochastic process and apply suitable probability distributions for the random variable generated from such process.
- Find probabilities using probability distributions.
- Use probability concepts and laws in decision analysis.

Course Contents:

Overview of the continuous random variables, Uniform, Beta, Lognormal, Exponential, Gamma, Laplace, Rayleigh and Weibull distributions with moments and cumulates Distributions of functions of random variables; Bivariate Normal distribution and its properties, Distributions of functions of random variables: Chi-square, t and F distributions, their derivations and properties. Central limit and Chebyshev's theorems, Weak and Strong Laws of large numbers and their applications, Order statistics, Distributions of r-th and s-th order statistics.

Pre-Requisite: STAT- 511

Books Recommended

1. Casella, G. and Berger, R.L. (2008). Statistical Inference, Cengage Learning, New York, USA.
2. Hirai, A.S. (2002), A Course in Mathematical Statistics, Ilmi Katab Khana, Lahore.

3. Hogg, R.M., McKean, J. and Craig, A.T. (2013). Introduction to Mathematical Statistics. Prentice Hall, New Jersey, USA.
4. Johnson, N.L., Kotz, S. and Balakrishnan, N. (1994). Continuous Univariate istributions, John Wiley & Sons, New York, USA.
5. Johnson, N.L., Kotz, S. and Kemp, A.W. (1993). Univariate Discrete Distributions, John Wiley & Sons, New York, USA.
6. Mood, A.M, Graybill, F.A. and Boes, D.C. (2007). Introduction to the Theory of Statistics, McGraw Hill, New York, USA.

STAT-522 Sampling Techniques-Il (4 Cr.Hrs.)

Course Objectives:

- To understand the concept of systematic, cluster, multistage and multiphase sampling techniques.
- Comparison among different sampling techniques.
- To learn ratio and regression estimations.
- To understand the non-response, their sources, and randomized response technique.

Learning Outcomes:

By completing this course the students will be able to:

- Use and implement of systematic and cluster sampling designs.
- Apply the multistage and multiphase sampling appropriately in real world problems.
- Estimate the population parameters by using systematic and cluster sampling techniques.

Course Contents:

Systematic sampling, Cluster Sampling. Efficiency of systematic sampling compared with simple random sampling, stratified random sampling and cluster sampling. Sub sampling, proportion to size (PPS)-Sampling, Double Sampling, Multistage and Multiphase sampling, Thomson Hurwitz estimator, Comparison of different sample designs. Sampling and non-sampling errors and their sources. Non-response, their sources and bias. Randomized response. Critical study of National sample surveys conducted in Pakistan: Census of Agriculture, Household Income and Expenditure Survey (HIES), Pakistan Demographic Survey (PDS) and National Population and Housing Census and Surveys (NPHCS).

Note: Practical's of this course shall include visits of the students to various national statistical organizations and a report submitted to this effect.

Pre-Requisite: STAT-512

Books Recommended:

1. Bethelem, J. (2009). Applied Survey Methods: A Statistical Perspective. Wiley.
2. Cochran, W.G. (1977). Sampling Techniques. John Wiley and Sons, 3rd ed, New York.
3. Des Raj and Chandhok P. (1998). Sample Survey Theory. Narosa Publishing House, New Delhi.
4. Kish, L. (1992). Survey Sampling. John Wiley, New York.
5. Singh, R. and Singh N, (1996). Elements of Survey Sampling. Kulwar, Dodrecht.

*Various publications of Pakistan Bureau of Statistics (PBS).

STAT-523 Experimental Designs and Analysis of Experiments (4 Cr.Hrs)

Course Objectives:

- This course provides the advanced knowledge of experimental designs and their uses in different disciplines.
- To provide basic and advanced learning of investigation for conclusions through planning and designing of experiments.
- To train students through innovative instruction in design theory and methodology that will help them in addressing the significance of experimental design in statistics and across the universal disciplines.

Learning Outcomes:

- Understand the basic concepts and applications of experimental design.
- Decide appropriate design for given scenario.
- Analyze the data generated from different designs and interpret the results.

Course Contents:

Introduction to factorial experiments, simple, main and interaction effects. Hidden replication. 2k and 3k series and mixed level factorial experiments and their analysis. Analysis of Covariance (ANCOVA). Confounding in factorial experiments, complete and partial confounding; Single replication of factorial experiments. Fractional factorial experiments. Introduction of response surface methods; first and second order designs, central composite designs, fitting of response surface models and estimation of optimum response, split plot design and its variations.

Pre-Requisite: STAT-513

Books Recommended:

1. Kehul, R.O. (2000). Design of Experiments: Statistical Principles of Research Design and Analysis, Duxbury/ Thomson Learning, New York, USA.
2. 3. Montgomery, D.C. (2012). Design and Analysis of Experiments, John Wiley & Sons, New York, USA
3. Montgomery, D.C. (2000). Design and Analysis of Experiments", John Wiley, New York.
4. Oehlert, G.W. (2000). A first course in design and analysis of experiments, W.H. Freeman, New York, USA.
5. Steel, R.G.D, Torrie , J.H. and Dickey D.A. (2008). Principles and Procedures of Statistics: A Biometrical Approach. McGraw-Hill, Michigan, USA.
6. Steel, G. D., Terrie, and Dickey A. (1997). "Principles and Procedures of Statistics: A Biometrical Approach" 3rd Edition, McGraw Hill, New York.
7. Boniface, DR. (1995). "Experimental Design & Statistical Methods", Chapman & Hall.
8. Myers, R.H. and Montgomery, D.C. (1995). "Response Surface Methodology; Process & Product Optimization Using Design", John Wiley.

STAT-524 Econometrics (4 Cr.Hrs)

Course Objectives:

- The purpose of this course is to introduce students to the main concepts and tools used in econometrics.
- In particular, to learn when and how to apply regression analysis. Learn the basic assumptions and techniques used to run estimations and make inferences in the context of a linear equation framework.
- To learn to recognize specification and data problems. Also additional tools to handle time series data.
- Each topic will be approached with a mix of intuitive explanations, theoretical characterization and proofs. And practical applications, including interpretation of regression output.

Learning outcomes:

- Conduct basic statistical and econometric analysis. Explain and interpret econometric results.
- Explain econometric concepts and results intuitively, conduct independent data analysis and inquiry using the tools of statistics and econometrics.
- Conduct Research with econometrics, derive econometric results mathematically

Course Contents:

Introduction to econometrics, Problems of autocorrelation, multicollinearity, heteroscedasticity and their solution; Ridge regression, Lagged variables, Autoregressive models. Dummy variables, Errors in Variables, Instrumental variables, System of simultaneous linear equations, Identification-Estimation method, indirect and two-stage least squares methods, restricted least squares. Test of identifying restrictions; Estimation with stochastic regressor, generalized least squares estimators.

Pre-Requisite: STAT-514

Books Recommended

1. Baltagi, B. H. (1999). "Econometrics", 2nd Edition, Springer Varlog.
2. Draper, N.R. and Smith, H. (2004). "Applied Regression Analysis", John Wiley, New York.
3. Draper, N.R. and Smith, H. (2004). "Applied Regression Analysis", John Wiley, New York.
4. Gujrati, D. (2004). "Basic Econometrics", John Wiley, New York.
5. Gujrati, D. (1998). "Econometrics", John Wiley, New York.
6. Montgomery, D.C., and Peck E.A. (1992). "Introduction to Linear Regression Analysis", 2nd Edition, John Wiley and sons Inc. New York.
7. Maddela, G.S. (1977). 'Econometrics", McGraw Hill. New York.

STAT-507 Population Studies (3 Cr.Hrs.)

Course Contents:

Meaning of vital statistics, registrations of Birth and death in Pakistan. Uses of vital statistics, short comings of vital statistics, rates and ratios (Sex ratio, child women ratio, birth and death ratio, population growth rate, classification of natal rates, death rates or mortality rates, crude death rate, specific death rate, infant mortality rate, case fatality rate, fertility rates, crude birth

rate, specific birth rate, standardized death rate, reproduction rates, morbidity or sickness rates, marriage rates, divorce rates etc. general; fertility rate, total fertility rate.)

Basic concepts of demography, Sources of demographic data: The population and housing census, Registration of vital events. Demographic surveys, Components of population growth, composition of population and vital events, Types and sources of errors, Data quality testing procedures, testing the accuracy of age and sex distribution, Fertility and mortality measures, Estimation from incomplete Data. Consequences of world population growth & population explosion. State of Population in Pakistan. Development of demographic profile in Pakistan. Recent demographic parameters. Current and future demographic activities in Pakistan.

Construction of complete and abridged life tables, Different types of life tables, Graphs of lx, qx and ex, Description and uses of life table columns.

Books Recommended

1. Jay Weinstein, Vijayan, K. Pillai, (2001) "Demography: The Science of Population". Allyn & Bacon.
2. Govt. of Pakistan (1998), National, Provincial and District census reports and other supplementary reports with respect to 1996 census; PCO, Islamabad.
3. United Nations (1996), "Added years of Life in Asia", ESCAP; U.N., Thailand.
4. Palmore, J .A; Gardner, R.W. (1994), "Measuring Mortality Increase"; East West Centre, Honolulu.
5. Impagliazo, J. (1993), Deterministic Aspects of Mathematical Demography, Springer Verlag New York.
6. United Nations (1990), " World Population Monitoring 1989", UNFPA.
7. Rukanuddin AR. and Farooqi, M.N.l.., (1988), "The State of Population in Pakistan — 1987", NIPS, lslamabad.
8. Keyfitz, N. (1983) "Applied Mathematical Demography", Springer Verlag N.Y.
9. Pollard, A.H., Yousaf, F & Pollard, G.M. (1982), "Demographic Techniques", Pergamon Press. Sydney.

   *Pakistan Demographic Survey, Govt. of Pakistan, Federal Bureau of Statistics.

   *Publications of population census organizations.

STAT-611 Statistical Inference: Estimation of Parameters (3Cr.Hrs)

Course Objectives:

- To introduces students to the basic theory behind the development and assessment of statistical analysis.
- To understand the techniques in the areas of point and interval estimation, as well as hypothesis testing.
- To apply the statistical techniques to real data and draw conclusions.

Learning Outcomes:

By completing this course the students will be able to:

- Explain the notion of a parametric model and point and interval estimation of the parameters of those models.
- Apply approaches for estimation and hypothesis testing.
- Explain and apply the idea of non-parametric statistics, wherein estimation and analysis techniques are developed that are not heavily dependent on the specifications of an underlying parametric model.
- Understand the computational issues related to the implementation of various statistical inferential approaches.

Course Contents

Estimation of Parameters. Properties of Estimators: unbiasedness, consistency, sufficiency, efficiency, completeness Cramer-Rao inequality, Rao-Blackwell and Lehmann - Scheffe Theorems. Methods of Estimation: Moments, Maximum likelihood, least-squares, minimum Chi- square and Bayes' method. Interval Estimation: Pivotal and other methods of finding confidence interval, confidence interval in large samples, shortest confidence interval, optimum confidence interval. Bayes' Interval estimation.

Pre-Requisite: STAT-406

Books Recommended

1. Lindgren, B.W. (1998). "Statistical Theory". Chapman and Hall, New York.
2. Mood, A.M., Graybill, F.A. and Boss, D.C. (1997). "Introduction to the Theory of Statistics". McGraw Hill, New York.
3. Rao, C.R., (2009). "Linear Statistical Inference and its Applications", John Wiley, New York.
4. Rohatgi, V. K. (1984) Statistical Inference. Courier Dover Publications.
5. Stuart, A. and Ord, J.K. (2009). Kendall's' "Advanced Theory of Statistics" Vol. II. Charles Griffin, London.

STAT-612 Multivariate Analysis-I (4 Cr.Hrs.)

Course Objectives:

- This course provides the fundamental knowledge of multivariate data and its applications in different fields of life.
- This course will introduce the student different multivariate techniques through real world problems.
- This course will develop the skill in students to estimate the parameters and drive inference in multivariate cases.

Learning Outcomes:

- Understand the basic concepts and applications of multivariate techniques.
- Unable to decide which multivariate technique to be used for the given scenario.
- Analyze the multivariate data and interpret the results correctly.

Course Contents:

Introduction to multivariate data and its graphical representation. Properties of Random Vectors, Data Matrix, Euclidean and statistical distance. Mahalanobis Distances and Angles Review of matrix algebra, quadratic form, Eigen analysis, spectral decomposition. Descriptive statistics for multivariate data, multivariate normal distribution and its properties, Distribution of Linear Combinations of Normally Distributed Variates. Basic Properties. Methods for testing multivariate normality, Inference about mean vector,

Inference about covariance matrices, One-way multivariate analysis of variance (MANOVA), and profile analysis.

Maximum Likelihood Estimation (MLE) of the Mean Vector and the Covariance Matrix. MLE under Constraints. Properties of the Estimators. Basic Multivariate Sampling Distributions. Distribution of Quadratic Forms Cochran's Theorem. The Wishart Distribution and its properties. The Hotelling T^2 Distribution. Distributions of Sample, Partial and Multiple Correlation Coefficients (Extensive derivations not required).Inference for the Multivariate normal Distribution. One-Sample Hypotheses on the mean Vector and covariance Matrix. One Sample Hypotheses of Linear Constraint on the Mean Vectors. Two Sample Hypotheses on the Mean Vectors and Covariance Matrices. Test of Homogeneity of Covariance Matrices. Test of Independence (Extensive Derivations not desired). Confidence Regions for the Mean Vectors. Simultaneous Confidence Intervals.

Books Recommended

1. Anderson, T.W. (2003). An Introduction to Multivariate Statistical Analysis, John Wiley & Sons, New York, USA.
2. Johnson, R. A. and Wichern, D. W. (2007). Applied Multivariate Statistical Analysis, Prentice Hall, New York, USA.
3. Kendall, M.G.(1975). "Multivariate Analysis" Charless Griffin and Co. Ltd. London.
4. Manly, B.F.J. (2004). Multivariate Statistical Methods: A Primer, Chapman and Hall/CRC, New York, USA.
5. Mardia, K. V., Kent, J. T. and Bibby, J. M. (1976). Multivariate Analysis, Academic Press, New York, USA.
6. Rencher, A.C. and Christensen, W.F. (2012). Methods of Multivariate Analysis, John Wiley & Sons, New York, USA.
7. Mardia, K.V., Kent, J.T. and Bibby, J.M. (1979). "Multivariate Analysis", Academic Press, London.

STAT-606 Survey and Research Methods (3Cr.Hrs.)

Course Objectives:

- To understand some basic concepts of research and its methodologies
- To identify appropriate research problems.
- To organize and conduct research in more appropriate manner
- To understand the logical structure of arguments and develop the reasoning ability.

Learning Outcomes:

- Knowledge of important aspects of critical thinking
- Understanding of research problems and questionnaire
- Understand general definition of research design
- Plan and conduct research using an appropriate research design, keeping in view the ethical issues in the research
- Critically review of research articles

Course Contents:

Definition of Research, Types of Research, Selection of Problem, Search of References, Formation of Hypothesis and Procedure for its Testing, Research Methodology, Planning of Experiments to Test Hypothesis Objectivity, Principals of Experimental Design, Steps in Experimentation, Collection of Data, Data Analysis to Determine Functional Relationship Between Variables, Levels of Significance, Interpretation of Results, Components of Scientific Reports and Various Methods of Data Presentation, Preparation of Scientific Reports, Publication Procedures.

Practical:

Studying and reviewing standard survey questionnaires and preparation of a sample questionnaire and a scientific report. Literature survey on a Given Topic, References from Various Sources. Critical report on given articles.

Books Recommended:

1. Blaxter, L., Hughes, C. and Tight, M. (2006) How to Research (third edition). Buckingham: Open University Press.
1. Creswell, J.W. (2002). Research Design: Qualitative, Quantitative and Mixed Methods Approaches. Sage Publications.
2. Daniel, P.S. and Sam, A.G. (2011). Research Methodology. Kalpaz Publications, Delhi. Salkind, N.J. (2010). Encyclopedia of Research Design. Sage Publications, Inc.
3. Gimbaled, J. and W.S. Acuter (1988) "MLA handbook for Writers of Research Papers", McGraw .The Modern Language Association of America.
4. Panneerselvam, R. (2013). Research Methodology. Prentice Hall India.
5. Singh, Y.K. (2011). Fundamental of Research Methodology and Statistics. New Age International limited.
6. Salmon, M. H. (2006). Introduction to Logic and Critical Thinking. 5th edition. Wadsworth Publishing.
7. Saris, W.E. and Gallhoffer, I.N. (2014). Design, Evaluation, and Analysis of Questionnaires for Survey Research. 2nd edition. John Wiley & Sons, Inc, Hoboken, New Jersey.

STAT-621 Statistical Inference (Hypothesis Testing) (3Cr.Hrs.)

Course Objectives:

- To develop an advanced-level understanding and working knowledge of statistical inference.
- To provide an introduction to the rudiments of statistical inference for population parameters based on a general decision theoretic framework covering estimation and test of hypothesis.
- To introduce some nonparametric methods and their applications.

Learning Outcomes:

- A foundation for understanding probability-based statistical inference material presented in other courses.
- The understanding of the concepts of testing, size and power of a test.
- The understanding of and derivation of the properties of tests based on different criterion functions.

Course Contents:

Tests of Hypotheses: Simple and composite hypotheses, critical regions. Neyman-Pearson Lemma, power functions, uniformly most powerful tests. Deriving tests of Hypothesis concerning parameters in normal, exponential, gamma and uniform distributions, Randomized Tests, Unbiased tests, Likelihood ratio tests and their asymptotic properties. Sequential Tests: SPRT and its properties, A.S.N. and O.C. functions.

Pre-Requisite: STAT-611

Books Recommended:

1. Hirai, A. S. (2012) Estimation of Parameters. Ilmi Kitab Khana Lahore.
2. Lehman, E.L. (2008). "Testing Statistical Hypotheses". Springler - Volga, New York.
3. Lindgren, B.W. (1998). "Statistical Theory". Chapman and Hall, New York.
4. Rao, C.R., (2009). "Linear Statistical Inference and its Applications", John Wiley, New York.
5. Stuart, A and Ord, J.K. (2009). Kendall's' "Advanced Theory of Statistics" Vol. II. Charles Griffin, London.
6. Welish, A. H. (2011) Aspects of Statistical Inference. Wiley.

STAT-622 Multivariate Analysis (Factor Analysis) (3Cr.Hrs.)

Course Objectives:

- This course provides the fundamental knowledge of orthogonal transformation of correlated variables.
- The course enable the students to use exploratory and confirmatory multivariate statistical methods properly.
- To be able to carry out multivariate statistical techniques and methods efficiently and effectively.

Learning Outcomes:

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

- Use principal component analysis effectively for data exploration and data dimension reduction.
- Use factor analysis effectively for exploratory and confirmatory data analysis.
- Discriminate between groups.
- Summarize, Analyse the multivariate data and interpret the results correctly

Course Contents:

Principal Component Analysis. Introduction. Definition and Properties of Principal Components. Sampling Properties of Principal Components. Inference about Principal components. Discarding of Variables. Interpretation of the Results. Factor Analysis Introduction. The Factor Model. Principal Factor Analysis. Maximum Likelihood Factor Analysis. Goodness of Fit Test. Factors Scores. Relationship between Factor Analysis and Principal Component Analysis. Discriminant Analysis. Introduction. Discrimination When the Populations are known. Discrimination under Estimation. Fisher's Linear Discriminant Function. Probabilities of Misclassification. Cluster Analysis. Introduction. A Probabilistic Formulation. Hierarchical Methods. Distances and Similarities. Other Methods and Comparative Approach. Canonical Correlation Analysis, Multidimensional Scaling, Correspondence Analysis.

Pre-Requisite: STAT-612

Books Recommended

1. Grimm. L.G. & Yarnold, P.R. (1995). "Reading and understanding multivariate statistics". Washington, DC: APA Books.
2. Grimm. L.G. & Yarnold, P.R. (2000). "Reading and understanding more multivariate statistics". Washington, DC: APA Books.
3. Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2009). "Multivariate data analysis" (7th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.
4. Everitt, B.S., Hothorn, T. (2011). "An introduction to Applied Multivariate Analysis with R", Springer.
5. Harlow, L. L. (2014). "The Essence of Multivariate Thinking: Basic Themes and Methods" (2nd ed.). New York: Routledge.
6. Johson, R. A., & Wichern, D. W. (2007). " Applied multivariate statistical analysis" (6^{th} ed.). NJ: Pearson
7. Lattin, J., Carroll, D., and Green, P. (2003). "Analyzing Multivariate Data". Thomson Learning.

STAT- Project/Internship (6 Cr.Hrs.)

Note: A separate and independent research project or internship with one optional course or two optional courses will be assigned and completed by each student. At the end of the project/internship, it will be mandatory for each student to submit his/her project/research/internship report for evaluation.

Elective Courses
(For 7th & 8th semester)

STAT-613 Statistical Quality Control (3Cr.Hrs.)

Course Objectives:

- This course is designed to provide a conceptual and practical knowledge of techniques for quality control.
- This course is structured to monitor the process control via control charts.
- This course is designed to determine most appropriate sample size needed to accept or reject a lot of material.

Learning Outcomes:

On the successful completion of this course the students will be able to:

- Design attribute and variable acceptance sampling plans for the industrial purpose.
- To construct various types of attribute and variable sampling plans using statistical software.
- Draw attribute and variable control charts to be implemented in different scenarios exist in industry.
- To construct various types of attribute and variable control charts to be implemented in different scenarios exist in industry.

Course Contents

Concept of quality control and Quality assurance, Total Quality Management (TQM), Statistical Methods in Quality Improvement, Statistical Process Control (SPC). X-bar, R, S, Shewhart, CUSUM and moving average control charts. Six Sigma approach to control charts, Average Run Length (ARL); Standard deviation run length (SDRL). Process capability analysis: Process improvements using design of experiments. Acceptance sampling plans: Single, double, and multiple with their operatic characteristic curves. Introduction to ISO- 9000 and ISO-14000 series

Books Recommended:

1. Juran, J.M. and Godfrey, A.B. (1998). *Juan's Quality Control Handbook*. McGraw Hill, New York, USA.
2. Montgomery, D.C. (2013). *Introduction to Statistical Quality Control.* McGraw Hill, New York, USA.
3. Ryan, T.P. (2011). *Statistical Methods for Quality Improvement.* John Wiley & Sons, New York, USA.
4. Schilling, E.G. and Neubauer, D.V. (2008). *Acceptance Sampling in Quality Control*. Chapman & Hall, New York, USA.
5. Vardeman, S.B. and Jobe, J.M. (2016). *Statistical Methods for Quality Assurance: Basics, Measurement, Control, Capability, and Improvement*. Springer, New York, USA

STAT-614 Applied Statistics (3Cr.Hrs).

Sampling: Need of sampling, Sample versus population, Random and nonrandom sampling, concepts of statistic and population parameter. Sampling techniques: Simple Random, Stratified and Systematic random sampling. Census and survey problem framing of questionnaire. Sampling and Non-Sampling Errors. Index numbers: construction and uses of index numbers,

un-weighted index numbers (simple aggregative index, average of relative price index numbers). Weighted index numbers (Laspayers, Peaches and Fishers ideal index numbers). Consumer price index (CPI) and Sensitive Price Indicators. Time Series Analysis: Components of time series and their isolation. Vital Statistics: Meaning of vital statistics, registrations of Birth and death in Pakistan. Uses of vital statistics, short comings of vital statistics, rates and ratios (Sex ratio, child women ratio, birth and death ratio, population growth rate, classification of natal rates, death rates or mortality rates, crude death rate, specific death rate, infant mortality rate, case fatality rate, fertility rates, crude birth rate, specific birth rate, standardized death rate, reproduction rates, gross reproduction rate, net reproduction rate, morbidity or sickness rates, marriage rates, divorce rates etc. general; fertility rate, total fertility rate.)

Books Recommended

1. Clark, G.M. and Cooke, D. (1998), "A Basic Course in Statistics" 4th ed, Arnold, London.
2. Mclave, J.T. Benson, P.G. and Snitch, T. (2005) "Statistics for Business & Economics" 9th Prentice Hall New Jersey.
3. Walpole, P.E. Myers, RH., Myers S.L. (1998), "Probability and Statistics for Engineers and Scientists", Prentice Hall.
4. Chaudhry, S.M. and S. Kamal, (1996), "introduction to Statistical Theory" Part I, II, 6th Ed, llmi Kitab Khana, Lahore, Pakistan.
5. Cochran, W.G. "Sampling Techniques".3rd Ed.
6. Pollard, A.H.. Yousuf, F. and Pollard G.M. (1982), "Demographic Techniques", Pergamon Press, Sydney.

STAT-615 Robust Methods (3Cr.Hrs.)

Course Objectives:

- The objectives of this course is to provide an introduction to both basic and advanced analytical tools for robust models. This course also aims to promote a critical perspective on the use of statistical informations.
- Beginning with simple statistical methods, the course builds to more robust analytical techniques such as multivariate linear regression and estimators.
- Emphasis is placed on theoretical understanding of concepts as well as the application of key methodologies used in different research fields.

Learning Outcomes:

At the end of this course the student shall be able to:

- Explain the importance, techniques and biases of estimators in context
- Explain the concept of outliers in regression model and other influential observations
- Construct and interpret various statistical hypothesis tests.

Course Contents:

Introduction to Robustness, Objective function, M-estimator of location, E-estimator, R-estimator and W-estimator, Redescending M-estimator's The Breakdown point of Robust estimator Influence function. M-estimator for scale, Jackknife Resampling, Outliers and influential observations, Outliers in Regression analysis.

Recommended Books:

1. Hamper, T.R. Brochette, E. M., Rousseau, P.J. and Satchel, W.A. (1986). *Robust Statistics: The approach Based on Influence functions,* John Wiley & Sons, New York, USA.
2. Hosmer, D.W. and Lemeshow, S. (2008). *Applied Survival Analysis,* John Wiley & Sons, New York, USA.
3. Huber, P. J. and Ronchetti, E.M. (2009). *Robust Statistics,* John Wiley & Sons, New York, USA.
4. Maronna, R.A., Martin, D.R. and Yohai, V.J. (2006). *Robust Statistics: Theory and Methods,* John Wiley & Sons, New York, USA.
5. Rousseau, P.J. and Leroy, A.M. (1987). *Robust Regression and outlier detection*, John Wiley & Sons, New York, USA.

STAT-616 Operations Research (3Cr.Hrs.)

Course Objectives:

- To introduce students to the techniques of operations research.
- To provide students with basic skills and knowledge of operations research and its application in industry.
- To introduce students to practical application of operations research with emphasis on the industrial data.
- To effectively use relevant statistical software for data analysis.

Learning Outcomes:

This course will enable the students to:

- Identify and develop operations research models from the verbal description of the real system.
- Understand the mathematical tools that are needed to solve optimization problems.
- Apply operations research techniques to summarize the industrial data.
- Demonstrate the usage of statistical software for solving problem and analyzing the relevant data.

Course Contents:

History and definition of Operations Research (OR), Types of OR models, Introduction to linear programming, Formulation of LP model, Graphical solution of two variables, Standard Form, Simplex method, Duality theory; Sensitivity Analysis, Primal and dual form, Transportation Problem, Assignment problem. Network Analysis, PERT/CPM techniques, Queuing Models.

Recommended Books:

1. Hillier, F.S. and Lieberman, G.J. (2014). *Introduction to Operations Research.* 10th edition. McGraw Hill.
2. Bazarra, N.M., Jarvis J.J. and Sherali, H.D. (2010). *Linear Programming and Network Flows*. 4th edition. John Wiley & Sons.
3. Taha, H.A. (2010). *Operations Research*. 9th edition, Pearsons.
4. Gross, D., Shortle, J.F., Thompson J.M. and Harris, C.M. (2008). *Fundamentals of Queueing Theory*. 4th edition. John Wiley & Sons, Hoboken, NJ.
5. Gupta, P.K. and Hira, D.S. (2008). *Operations Research*. 7th edition, S. Chand and Co., New Delhi.
6. Bronson, R. and Naadmuthu, G. (1997). *Operations Research – Schaums' Outline Series*. McGraw-Hill.

STAT-617 Statistical Practicum (3Cr.Hrs.)

Course Objectives:

- To discuss and explain application of the statistical techniques on real world problems.
- To use statistical software's to carry practical application of statistics.
- To apply statistical software to analyze and evaluate data by implementing appropriate statistical techniques.

Learning Outcomes:

Upon successful completion of the course the students will be able:

- Analyze a statistical question involving, sampling, design of experiments, regression using statistical simulation and real data sets.
- Apply various statistical techniques on benchmark data sets.
- To demonstrate an understanding of the concepts of statistical theory in application.
- To apply appropriate usage of software/programming languages.
- To analyze and communicate the results of statistical analysis accurately and effectively.

Course Contents:

This course enables students to gain professional work experience in the application of statistics. The students will carry practical on benchmark data sets using statistical software's/ programming packages. The numerical problems from regression analysis, sampling, experimental design, non-parametric technique.

Books Recommended:

1. Friedman, J., Hastie, T., & Tibshirani, R. (2001). The elements of statistical learning (Vol. 1, No. 10). New York: Springer series in statistics.
2. Crawley, M. J. (2012). The R book. John Wiley & Sons.
3. Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.
4. Verzani, J. (2018). Using R for introductory statistics. Chapman and Hall/CRC.
5. Gandrud, C. (2016). Reproducible research with R and R studio. Chapman and Hall/CRC.
6. Finch, W. H., Bolin, J. E., & Kelley, K. (2016). Multilevel modeling using R. Crc Press.
7. Morgan, G. A., Leech, N. L., Gloeckner, G. W., & Barrett, K. C. (2004). SPSS for introductory statistics: Use and interpretation. Psychology Press.

STAT-618 Bio-statistical Analysis (3Cr.Hrs.)

Course Objectives:

- To discuss and explain what biostatistics is and how it is used in Biological Sciences
- To recognize and give examples of different types of data arising in Biological Sciences
- To use statistical techniques to summarize the Biological data
- To apply statistical software to analyze and evaluate Biological data

Learning Outcomes:

- Understand the diverse applications of statistical tools in biological science.

- Demonstrate an understanding of the central concepts of modern statistical theory in Biological Sciences.
- Acquire the understanding of the appropriate usage of software for Biological sciences.
- Analyze and communicate the results of statistical analysis accurately and effectively.

Course Contents:

Definition of Biostatistics, type of variables and observations in biological, health and medical sciences, Uniqueness in terms of behavior of variables their domain, and units; Categorical, numerical and censored data. Populations, Target populations and samples; Role of sampling in biostatistics, Size of samples of various types of studies, Proportions, rates and ratios; incidence, prevalence and odds. Distributional behavior of biological variables (Binomial, Poisson and Normal), Role of transformation for analysis of biological variables. Probit and Logit transformations and their analysis, p values, its importance and role. Confidence Interval in simple and composite hypothesis testing.

Books Recommended:

8. Alfassi Z. B., Boger, Z. and Ronen, Y. (2005): *Statistical Treatment of Analytical Data*. Blackwell Science, USA.
9. Antonisamy, B. Premkumar, P. and Christopher, S. (2017). *Principles and Practice of Biostatistics*. 1st edition. Elsevier, India.
10. Daniel, W.W. (2010). *Biostatistics: A Foundation for the Health Sciences*. 6th edition. John Wiley, New York. NY, USA.
11. Dunn, G. and Everit, B. (1995). *Clinical Biostatistics*. Edward Arnold, London, UK.
12. Sullivan, M.L. (2018). *Essentials of Biostatistics in Public Health*. 3rd edition. Jones and Bartlett Learning, Burlington, MA, USA.
13. Zar, J. (2000). *Biostatistical Analysis.* 5th Edition. John Wiley & Sons, New York, NY, USA.

STAT-619 Official Statistics (3Cr.Hrs.)

Course Objectives:

- To understand the official, demographic and social statistics.
- To understand the scope and organization of official statistics,
- To understand the planning and administration statistics.

Learning Outcomes:

- The versatility to work effectively in a broad range of analytic, scientific, government, financial, technical and other positions.
- A broad overview of the fundamental issues underlying the organization of official statistics.
- To recognize the importance of statistical thinking.

Course Contents:

Design and planning of a Statistical Investigation. Data collection-approach and operation; Role of sampling in generation of Statistics, Sampling plans and survey Designs. Sources of Errors, Types of Errors, methods of their control. Data processing, presentation, and publication of Statistics. Different modes of Data Dissemination. Official Statistics, Statistical systems and standards, Sources of official statistics, their role, working and publication. Role of Official Statistics, Official Publications. Setup of official organizations in Pakistan their role, working & publication, Statistics Division, Federal Bureau of Statistics, Agricultural Census Organization,

Population Census Organization, Ministry of Food, Agriculture and Livestock; National Data Base and Registration Authority (NADRA). Provincial Bureaus of Statistics. Financial Statistics: Ministry of Finance, State Bank of Pakistan-Department of Statistics, their working, publications and responsibilities. Other Organization's Statistical output, National and International series, classification and standards. Use of Statistics in administration and planning. Concepts and evaluation of GDP, GNP, NNP, Balance of Trade and payments. Measurement of Income Distribution, use of Index Numbers and time series. Deflation and Inflation of series. National sample surveys and censuses conducted in Pakistan.

Assignment: Visit of major Statistical Organizations will be a part of the course. An assignment will have to be submitted on any topic given by the course In-charge.

Books Recommended:

1. Hansen M.H. (1980). "Progress and Problems in Survey Methods and Theory". Illustrated by the work of U.S. Bureau of the Census, U.S. Department of Commerce; A Monograph.
2. Kish, L. (1992). "Survey Sampling", John Wiley, New York.
3. Murthy, MN. (1979). "Quality of Data, Country Course on Sample Surveys", Karachi.
4. Statistics Division, "Activity Report" (1988-89). Government of Pakistan, Islamabad.
5. Statistical Institute for Asia & Pacific SIAP (1984). "Training of Trainers in Statistical Operations and Procedures" Part-I, II UNDP, Tokyo.

Suggested Reports:

- Hansen M.H. (1980). Progress and Problems in Survey Methods and Theory. IIIustrated by the work of U.S. Bureau of the Census, U.S. Department of Commerce; A Monograph.
- NIPA (1962). Administrative uses of Statistics. NIPA Karachi.
- Statistical Institute for Asia and Pacific SIAP (1984). Training of Trainers in Statistical Operations and Procedures. Part-I, II UNDP, Tokyo.
- Statistics Division (1979). Retrospect, Perspective and Prospect. Islamabad.
- Statistics Division Activity Report (1988-89). Government of Pakistan, Islamabad.
*Various Publications of PBS, State Bank of Pakistan, Ministry of Finance, etc.

STAT-620 Categorical Data Analysis (3Cr.Hrs.)

Course Objectives:

- To understand the basic concepts of categorical data analysis
- To recognize different types of categorical data and use appropriate methodology for categorical data
- To conduct statistical analysis using existing software and properly interpret the computer output.

Learning Outcomes:

Upon the successful completion of this course the students shall be able to:

- Implement basic categorical methods and combine them for the sampling estimation
- Obtain estimators, evaluate standard errors, construct confidence intervals and making statistical inference according to the categorical analysis techniques
- Apply the principles of lifelong learning to any new challenges arise with categorical data
- Demonstrate the knowledge to characterize, analyze and solve a wide range of problems related to the categorical data

Course Contents:
A brief history of categorical data analysis, Principles of likelihood-based inference, Sampling distributions for contingency tables, Measures of association for 2x2 tables, Testing independence in contingency tables, Exact inference for two-way tables, Inferences for three-way tables.
Introduction to generalized linear models: Log linear models, fitting Log linear and Logit models, building and applying Log linear models, Log linear Logit models for ordinal variables, multinomial response models for matched pairs, analyzing repeated categorical response data, logistic regression models and their analysis. Logistic regression, Model building, Alternative link functions for binary outcome, Diagnostics, Receiver Operating Characteristic (ROC) Curve Analysis. Exact methods and conditional logistic regression, Methods for analyzing matched case-control data, Multinomial response models for nominal data, Multinomial response models for ordinal data.

Books Recommended

1. Agresti, A. (2012). *Categorical Data Analysis.* 3rd edition. John Wiley & Sons.
2. Agresti, A. (2007). *An Introduction to Categorical Data Analysis*. 2nd edition. John Wiley & Sons.
3. Collett D. (2003). *Modeling Binary Data*. Champman and Hall/CRC.
4. Hosmer D. W. and Lemeshow S. (2004). *Applied Logistic Regression.* John Wiley & Sons.
5. Lloyd C. J. (1999). *Statistical Analysis of Categorical Data.* John Wiley & Sons.
6. Powers D. A. and Xie, Y. (2008). *Statistical Methods for Categorical Data Analysis.* 2nd edition. Emerald Group publishing.

STAT-623 Stochastic Processes (3Cr.Hrs.)

Course Objectives:

- This course aims to provide an understanding of stochastic processes and the ability to analyse certain aspects of these processes.
- Accordingly, the course starts by reviewing probability theory, conditional probability, independence and certain properties of random variables, and continues by examining stationary processes.
- Furthermore, Markov chains in discrete and continuous time as well as Possion processes are investigated in detail.

Learning Outcomes:
Upon completion of this course the students shall:

- Define probability models, concept and properties of random variables, random processes, Markov processes and Markov chains,
- Explain properties and functions of random processes with stochastic mathematical models, - formulate discrete and continuous time random processes, stationary random processes.
- Devise solutions with probability models for Poisson processes, discrete and continuous time Markov chains.

Course Contents:
Introduction. Generating Functions. Laplace Transforms. Difference Equations. Differential – Difference Equations. Introduction to Stochastic Processes. The Random Walk in one and two Dimensions. The Classical Gambler's Ruin Problem. Expected Duration of the Game. Markov

Chains: Definition. Transition Probabilities, Higher Transition Probabilities. Classification of States and Chains. Markov processes with Discrete State Space. Poisson Process and its Generalization. Pure Birth and Death Processes. Markov Processes with Discrete State Space (Continuous Time Markov Chains). Markov Processes with Continuous State Space. Introduction to Brownian Motion. The Wiener Process. Diffusion Equations for the Wiener Process. Introduction to Brownian motion.

Books Recommended

1. Durrett, R. (2001). *Probability: Theory and examples*, Cornel University, New York, USA.
2. Freedman, D. (1999). Brownian motion and Diffusion, Springer, New York, USA.
3. Karlin, S.A. and Taylor, H.M. (2011). *A first course in Stochastic Process*, Academic Press, London, USA.
4. Peter, W.J. and Smith, P. (2010). *Stochastic Process: An Introduction*, Chapman and Hall, New York, USA.
5. Resnick, S. I. (2002). *Adventure in Stochastic Process*, Birkhauser Boosters, New York, USA.
6. Ross, S.M. (2006). *Stochastic Process*, John Wiley & Sons, New York, USA.

STAT-624 Time Series Analysis (3Cr.Hrs.)

Course Objectives:

- Learn basic analysis of time series data.
- Compute and interpret ACF/PACF and a sample spectrum.
- Derive the properties of ARIMA models and choose an appropriate ARIMA model for a given set of data and fit the model using an appropriate package
- Compute forecasts for a variety of linear methods and models.

Learning Outcomes:

After successfully completing this course the students shall:

- Demonstrate understanding of the concepts of time series and their application to various fields of sciences.
- Apply ideas to real time series data and interpret outcomes of analyses and forecast.
- Use various advanced time series econometric methods, estimation methods and related econometric theories.
- Interpret time series models' estimates and analyze the results.

Course Contents:

Time series analysis: concepts and components, Stochastic Process, Stationary Time-Series, Exponential smoothing techniques, auto-correlation and auto-covariance, estimation of auto-correlation function (ACF) and Partial autocorrelation function (PACF) and standard errors, Periodogram, spectral density functions, comparison with ACF, Linear stationary models: Auto Regressive Moving Average (ARMA) and mixed models, Non-stationary models, general ARIMA notation and models, minimum mean square forecasting. ARIMA Seasonal Models

Books Recommended

1. Anderson, T. W. (2011). *The statistical analysis of time series* (Vol. 19). John Wiley & Sons.

2. Box, G.E.P. and Jenkins, G.M., and Reinsel G. C. (2008) Time Series Analysis: Forecasting and Control, San Francisco.
3. Chatfield C. (2003): The Analysis of Time Series: An Introduction, Taylor & Francis, NY, USA.
4. Diggle, P.J. (1990), Time Series: A Bio statistical Introduction, Clarendon Press, Oxford.
5. Enders, W. (2004). Applied time series econometrics. *Hoboken: John Wiley and Sons*.
6. Jonathan D. C. and Kung-Sik C. (2008): Time Series Analysis with Applications in R, Springer, USA.
7. Peter J. B and Richard A. D (2002): Introduction to Time Series and Forecasting, Second Edition, Springer, USA.

STAT-625 Decision Theory (3Cr.Hrs.)

The nature and concept of loss functions, parameters, decisions and sample spaces. Risk and average loss. Admissibility and the class of admissible decisions. Minimax principle and its application to simple decision problems, linear and quadratic losses and their uses in problems of estimation and testing hypotheses. Asymptotically minimax procedure. A prior distributions and conjugate priors. Bayes' decision procedure, admissibility of Bayes' and minimax procedures.

Books Recommended

1. Berger, J. 0. (1985). "Statistical Decision Theory & Bayesian Analysis", Springer Verlag.
2. Blackwell, D. and Graphic, M.A. (1966). "Theory of Games and Statistical Decision", John Wiley. New York.
3. Joyce, J. M. (1999). The foundations of causal decision theory. Cambridge University Press.
4. Liese, F., & Miescke, K. J. (2007). Statistical decision theory. In Statistical Decision Theory (pp. 1-52). Springer, New York, NY.
5. Lindgren, B.W. (1971), "Elements of Decision Theory, Macmillan", New York.
6. Parmigiani, G., & Inoue, L. (2009). Decision theory: Principles and approaches (Vol. 812). John Wiley & Sons.
7. Winkler, R. L. (1972). An introduction to Bayesian inference and decision (pp. 493-524). New York: Holt, Rinehart and Winston.

STAT-626 Reliability Analysis (3Cr.Hrs.)

Course Objectives:

- To learn to analyze complete and censored reliability data with and without covariates.
- To learn some key methods in reliability modeling.
- To learn the probability and statistical methods covered in the Reliability Analysis.
- To have the working knowledge to determine the reliability of a system and suggest approaches to enhancing system reliability.

Learning Outcomes:

Having completed the course, the successful students will be able to:

- Analyse the interference between strength and stress, or life data for estimating reliability
- Apply the appropriate methodologies and tools for enhancing the inherent and actual reliability of components and systems, taking into consideration cost aspects.

- Specify life test plans for reliability validation.

Course Contents:
Basic concepts of reliability. Structural reliability. Lifetime distributions (Failure models): Hazard rate; Gamma, Weibull, Gumball, Log-Normal and Inverse Gaussian Distribution. Stochastic fatigue-rate models. Point and interval estimation. Fatigue-life model. Testing reliability hypothesis. Monte-Carlo, distribution-free and Bayes' methods in reliability. System reliability, series and parallel systems. Failure models, (kout-of-rn) New-better-than used models. Inferences for these models. Accelerated life testing.

Books Recommended

1. Achintya Haldar, Sankaran Mahadevan (2000). Reliability Assessment Using Stochastic Finite Element Analysis".
2. Crowder, M .J. (1994). "Statistical Analysis of Reliability Data".
3. Gertsbakh, lB. (1989). "Statistical Reliability Theory". Marcel Decker. New York.
4. Lee, J. Bain, Bain Bain, (1991). "Statistical Analysis of Reliability and Life-Testing Models".
5. Gertsbakh, lB. (1988). "Statistical Reliability Theory".
6. Lawless, J.F. (1982). "Statistical Model and Methods for Lifetime Data".
7. Mann, N.R., Scheefer, R.E. and Singapoor wel, N.D. (1974). "Methods for Statistical Analysis of Reliability", John Wiley & Sons.

STAT-627 Survival Analysis (3Cr.Hrs.)

Course Objectives:
- To introduce the basic concepts of survival analysis
- To describe and explain how survival analysis can be applied in different fields
- To learn the usage of appropriate statistical software for survival data analysis

Learning Outcomes:
- Understand the basic concepts and ideas of survival analysis
- Derive properties and methods for standard survival time distributions
- Perform and interpret simple non-parametric survival analyses using software
- Apply and interpret semi-parametric regression models for survival data using software

Course Contents:
Describing the probability distributions of the survival and hazard functions. Basic layout of the survival problem both manually and computer based presentation of survival data. Computation of the descriptive measures for survival data both graphically and empirically.
Estimation of the survival function, survival probabilities. Estimation of the survival functions from possibly censored samples by means of the Kaplan-Meier estimator, the Nelson-Aalen estimator and the kernel density estimator or the Ramlau-Hansen estimator and comparisons of k independent survival functions by means of the generalized log-rank test and related alternative approaches. The Proportional Hazards Model, the likelihood function, the Partial Likelihood Function, identification of Significant Covariates, estimation of the Survivorship Function with Covariates. Cox's semi-parametric models. Evaluation of the assumptions of Cox proportional hazard model. Introduction to estimation of Stratified Cox's procedures for single and multiple variable adequacy Assessment of the Proportional Hazards Model.

Books Recommended:

1. Collet, D. (2014). *Modelling Survival Data in Medical Research*. 3rd edition, CRC Press, Taylor and Francis Group. Fl, USA.
2. Gjessing, H., Aalen, O. O. and Borgan, O. (2012). *Survival and Event history analysis*. Springer Series, New York, NY, USA.
3. Kleinbaum, D.G. and Klein, M. (2012). *Survival Analysis: A self-learning text*. 3rd edition. Springer, New York, NY, USA.
4. Klein, J. P., and Moeschberger, M. L. (2003). *Survival Analysis: Techniques for Censored and Truncated data*. 2nd edition, Springer series, New York, NY, USA.
5. Lee, E. T., and Wang, J. W (2013). *Statistical Methods for Survival Data Analysis*, 4th edition, John Wiley & Sons, New Jersey, USA.
6. Machin, D., Cheung, Y. B. and Parmar, M. K. (2006). *Survival Analysis: A practical approach*. 2nd edition, John Wiley & Sons, Ltd. England, U.K.

STAT-628 Data Mining (3Cr.Hrs.)

Course Objectives:

The course is designed to enable the students to:

- interpret the contribution of data warehousing and data mining to the decision-support level of organizations
- Understanding of pattern mining, association, correlation, classification, prediction, and cluster and outlier analysis
- Have knowledge different classification methods

Learning Outcomes:

Students who successfully complete this course should be able to:

- design and implement systems for data mining
- evaluate the performance of different data-mining algorithms
- decision through classification and regression trees

Course Contents:

Introduction to databases including simple and relational databases, data warehouses, Review of classification methods from multivariate analysis; classification, decision trees: classification and regression trees. Clustering methods from both statistical and data mining viewpoints; vector quantization. Unsupervised learning from univariate and multivariate data; dimension reduction and feature selection. Supervised learning from moderate to high dimensional input spaces; introduction to artificial neural networks and extensions of regression models.

Books Recommended:

1. Tan, P., Steinbach, M. & Kumar, V. (2006). *Introduction to Data Mining*, Addison Wesley, New York, USA.
2. Benson and Smith, S.J. (1997). "*Data Warehousing, Data Mining'*, and OLAP. McGraw-Hill.
3. Bramer M (2007): *Principles of Data Mining*. Springer-Verlag London Limited UK.
4. Breiman, L. Friedman, J.H. Olshen, R.A. and Stone, C.J. (1984). "*Classification and Regression Trees"* Wadsworth and Brooks/Cole.
5. Han, J., Kamber, J. Pei, J., and Burlington, M. A. (2012) Data mining: concepts and techniques. Haryana, India.
6. Han, J. and Camber, M. (2000). Data Mining; "*Concepts and Techniques*". Morgan Gaufmann.

7. Mitchell, T.M. (1997). *"Machine Learning*". McGraw-Hill.
8. Rao C. R., Wegman E. J. & Solka J. L (2005): *Handbook of Statistics, Vol. 24: Data mining and data visualization*. Elsevier B.V., North Holland.

STAT-629 Actuarial Statistics (3Cr.Hrs.)

Course Objectives:

- To develop understanding of the mathematical concepts and techniques that are used by actuaries to model stochastic processes of both assets and liabilities.
- To learn about various types of insurance and pension schemes.

Learning Outcomes:

- Basic Mathematics involved in Actuarial Computations.
- Insurance, Types and Applications in Pakistan.
- Understanding the Life Contingencies and Actuarial Notations.
- Understanding the Life Tables, Types and Computations.

Course Contents:

Utility theory. Insurance and unity theory, models for individual claims and their sums survival function curate future lifetime, force of mortality. Life table and its relation with survival function. Examples. Assumption for tractional ages. Some analytical laws of mortality, select and ultimate tables multiple life functions. mint life and last survivor status, insurance and annuity benefits through multiple life function evaluation for special mortality laws Multiple decrement models, deterministic and random survivorship groups, associated single decrement tables, central rates of multiple decrement. Net single premiums and their numerical evaluations Distribution of aggregate claims compound Poisson distribution and its applications.

Life Tables: Describe the life table functions, express life table probabilities in term of the actuarial related functions used both in assurances and annuities. Evaluation of assurances and annuities: derive the relations between assurance and annuities and their select and continuous equivalents. Net premiums and provisions: ultimate and select mortality; net premiums and net premium provisions, random future loss, , prospective and retrospective provisions, Derive Thiele's equation, Death strain at risk, expected death strain, actual death strain, mortality benefits, Simple annuities and assurances involving two lives. Mortality: Theories of Mortality, analytical laws of mortality, techniques of projections of population mortality. Pension Theory: Structure and design of pension funds, Basic actuarial aspects of pension plans, Actuarial assumptions and actuarial cost methods, periodic gain and loss analyses, Relative merits of cost methods, sensitivity analysis.

Books Recommended:

1. Booth, P.M. et al. (1999). Modern Actuarial Theory and Practice, Chapman & Hall.
2. Bowers, N.L. Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J. (1997). Actuarial Mathematics, Society of Actuaries, 2nd Edition.
3. Broverman, S.A. (2015). Mathematics of Investment and Credit, 6th Edition, ACTEX Publications.
4. Daniel, J.W. and Vaaler, L.J.F. (2007). Mathematical Interest Theory, Pearson, Prentice Hall.
5. Dickson, D.C.M. Hardy, M.R. and Waters, H.R. (2013). Actuarial Mathematics for Life Contingent Risks, 2nd Edition.

6. Gerber, H.U. (1997), Life Insurance Mathematics, Springer-Verlag, 3rd Edition
7. Johnson, A. (2016). Actuary Career (Special Edition): The Insider's Guide to Finding a Job at an Amazing Firm, Acing the Interview & Getting Promoted.

Miller, T. (2015). Achieving Your Pinnacle: A Career Guide for Actuaries.

STAT-630 Mathematical Modeling and Simulation (3Cr.Hrs.)

Course Objectives:

- To understand the mathematical models using simulation
- Knowledge of simulation approaches to problem solving, on a diverse variety of disciplines.
- To check the validity of models.

Learning Outcomes:

After completion of this course the students shall be able to:

- Recognize the connections between simulated and real data.
- Familiar with a variety of simulated examples where mathematical models helps accurately explain physical phenomena.
- Able to independently expand their mathematical or statistical expertise when needed, or for interest's sake.

Course Contents:

Monte Carlo methods: Different methods of generating random variables, generation of random numbers, acceptance and rejection techniques from various distributions. Comparison of algorithms to generate random variables. Generating random variables from failure rates. Generation from multinomial distribution / Monte Carlo integration. Gibbs sampling and other techniques. Variance reduction techniques: importance sampling for integration, control varieties and antithetic variables.

Books Recommended:

1. Daniel P. M, Maynard T. (2006). Mathematical Modeling and Computer Simulation, Thomson Brooks/Cole
2. Fishman, G.S. (1996). Monte Carlo: Concepts, Algorithms, and Applications. Springer.
3. Ross, S.M. (2002). Simulation, 3rd Edition. Academic Press.
4. Ripley, B.D. (1987) "Stochastic Simulations" (Wiley)
5. Velten, K. (2009). Mathematical modeling and simulation. Wiley VCH, Germany.

STAT-631 Bayesian Inference Crdt Hrs 3

Course Objectives:

- The aim of this course is to introduce the modern approach to Bayesian statistics,
- This course is emphasizing the computational aspects and the differences between the classical and Bayesian approaches.
- This course will help in formulating appropriate Bayesian models, including data and prior distributions.

Learning Outcomes:

- Understanding basic techniques of Bayesian statistics for decision making
- Using different simulation techniques to handle complex posterior distribution
- Knowing the application of Bayesian statistics in different models

Course Contents:
Introduction to Bayesian Inference, goals of Bayesian Inference, Conditional Probability, Conditional independence, Prior distribution and its different types, Posterior distribution, its mean, median (Bayes estimators under loss functions) and variances. Posterior Inference based on one parameter e.g. binomial, Poisson etc. Posterior inference based on normal distribution: Posterior predictive distributions, Bayesian Hypotheses Testing: Bayes factor; The highest density region; Introduction to Monte Carlo method, Discrete approximations.

Recommended Books:

1. Albert, J. (2007). Bayesian Computation with R, 1st ed. Springer, New York, USA.
2. Carlin, B. P. and Louis, T. A. (2008). *Bayesian Methods for Data Analysis*. Chapman & Hall/CRC Press, New York, USA.
3. Congdon, P. (2006). *Bayesian Statistical Modelling*, John Wiley & Sons , New York, USA.
4. Gelman, A., Carlin, J. B., Stern, H. S. and Rubin, D. B. (2014). *Bayesian Data Analysis*. Chapman & Hall/CRC Press, New York, USA.
5. Hoff, P.D. (2009). *A First Course in Bayesian Statistical Methods*, Springer, New York, USA.

Department of Statistics

Curriculum of M.Phil Statistics
2019-Onwards

M.Phil Statistics

PROGRAM OBJECTIVES:

The postgraduate programmes in Statistic are specifically designed to enhance the career prospects and research expertise of the students and to enable them to contribute their expertise in different fields. The program provide a balance of statistical theory and practical applications. The designed courses build students' knowledge in all areas of statistics and enable them to promote collaborations and inter disciplinary relationship with other fields of studies.

Details of the Program

Title of the Program	M.Phil Statistics
Duration of the Program	Two years, comprises of 4 semesters (Two semesters for course work and two semesters for research)
Total No. of Credit Hours	30 Credit Hours A minimum of 24 Credit Hours of Course Work + 06 Credit Hours for Thesis (Two semester in the first year comprises of 12 credit hours each and the final two semesters, in the second year, for thesis / research equivalent to 6 Credit Hours.)
Semester Duration	16 weeks of Teaching (excluding Examinations)
Course Load Per Semester	9-12 Credit Hours

Scheme of Studies, M.Phil Statistics

Year	Course Code	Course Title	Credit Hours
1st Year		**SEMESTER 1**	
	STAT-712	Research Methodology	3
	STAT-715	Major-I	3
		Major-II	3
		Major-III	3
		Total	**12**
		SEMESTER 2	
	STAT-716	Advanced Statistical Packages	3
		Major-IV	3
		Major-V	3
		Major-VI	3
		Total	**12**
2nd Year		**SEMESTER 3 and 4**	
		Thesis	6
		Total	**30**

List of Courses

Course Code	Course Title	Credit hours
MINOR COURSES		
STAT-711	Survey Sampling	3
STAT-712	Research Methodology	3
STAT-713	Theory of Linear Models	3
STAT-714	Measure Theory	3
STAT-715	Categorical Data Analysis	3
STAT-716	Advanced Statistical Packages	3
MAJOR COURSES		
STAT-717	Economics for Statisticians	3
STAT-718	Advanced Statistical Inference	3
STAT-719	Advanced Regression Analysis	3
STAT-720	Applied Multivariate Analysis	3
STAT-721	Applied Survival Data Analysis	3
STAT-722	Applied Stochastic Models	3
STAT-723	Mathematical Modeling and Simulation	3
STAT-724	Spatial Data Analysis	3
STAT-725	Applied Operation Research	3
STAT-726	Advanced Statistical Methods in Quality Control	3
STAT-727	Time series Analysis and Forecasting	3
STAT-728	Classification and Regression Trees	3
STAT-729	Applied Biostatistics	3
STAT-730	Statistical Consulting	3
STAT-731	Demographic Methods	3
STAT-732	Meta-Analysis	3
STAT-733	Social Network Analysis	3
STAT-734	Advanced Experimental design	3
STAT-735	Applied Smoothing Techniques	3
STAT-736	Statistical Genetics	3
STAT-737	Environmental Statistics	3
STAT-738	Regression Models for Count Data	3
STAT-739	Non-Linear Statistics	3
STAT-740	Big Data Analysis	3
STAT-741	Non-Parametric Methods	3
STAT-742	Machine Learning	3
STAT-743	Pattern Recognition	3

DETAILS OF THE COURSES

STAT-711	Survey Sampling	(3Cr.Hrs.)

Course Objectives:

- To understand the different types of errors involved in planning and running surveys
- To know how to minimize the error arises in sampling surveys
- To critically evaluate the quality and data analysis of complex surveys

Learning Outcomes:

- Demonstrate knowledge and understanding of the stages involved in planning and running surveys, knowing the error might arises in each of these and how to minimize.
- Achieve an understanding of the diverse methodological issues arising in sample survey research and the relationships between them.
- Demonstrate knowledge and understanding of the compromises that exist in survey design, and the strengths, weaknesses and suitability of each option.

Course Contents:

Non-Sampling Error, Observational Errors, Incomplete Sampling, Non-Response, Effect of Non-Response, Response and Response Variance, Sources of Response Error, Detection, Control and Measurement of Response Error, Scaling Methods, Types of Scales, General Procedure in Attitude Scaling, Rating Scales, Likert Scales, Guttman Scales, Sematic Differential, A Survey of Superpopulation Models, Optimal Design-Unbiased Strategies Model G_T, Optimal Design-Unbiased Model E_T, Predicting the Population Mean, Results on Optimal Unbiased Prediction, Prediction Without Auxiliary Information, Model G_R, Juging the Uncertainty of the Estimation, Prediction Using Auxiliary Information, Model $G_{MR,}$, Regression Analysis for Complex Survey Design on Regression Analysis, Effect of Two-Stage Sampling on OLS Methods, Comparison of Domain Means in Two-Stage Sampling.

Recommended Books:

1. Blair, E., & Blair, J. (2014). Applied survey sampling. Sage Publications.
2. Cochran, W.G. (1996). Sampling Techniques. John Wiley and Sons, New York.
3. Krewski, D., Platek, R., and Rao, J. N. (Eds.). (2016). Current Topics in Survey Sampling: Proceedings of the International Symposium on Survey Sampling Held in Ottawa, Canada, May 7-9, 1980. Elsevier.
4. Mukhopadhyay, P. (2005). Theory and Methods of Survey Sampling. Prentice-Hall of India.
5. Valliant, R., Dever, J. A., and Kreuter, F. (2013). Practical tools for designing and weighting survey samples. New York: Springer.

STAT-712 Research Methodology (Crdt.Hrs.3)

Course Objectives:

- To develop the reasoning ability to the students
- To understand the logical structure of arguments
- To emphasis on acquiring a working knowledge of statements, symbolism, logical connectives, logical relations, basic deductive inferences, truth tables and validity.

Intended Learning Outcomes:

Upon successful completion of this course the students will have:

- Knowledge of important aspects of critical thinking
- Strong basis in methods of Boolean algebra and truth tables
- Understanding of research problems and questionnaire

Course Contents:

What is logic, Logic as a science and an art, laws of thought, propositions, Arguments, Propositions and Arguments, Recognizing Arguments, Deductive and inductive Arguments, Validity and truth, Classes and Categorical positions, symbolism and diagrams for categorical syllogism, figures of the syllogism, Venn Diagram Technique for testing syllogism, Symbolic Logic, Negation and disjunction, truth tables, Concept of boolean algebra, Truth trees, decision trees. Theory and Fact, Sources and Properties of Hypothesis, Formation of Research Problem and its Significance, preparation of research design, components of research design, questionnaires and interviews, preparation of research report, Multidimensional scaling.

Research Design, Components of Research Design, Questionnaires and Interviews, Preparation of Research Report, References style, publication requirement, Impact factor, Choosing appropriate general for the Journal, Latics.

Recommended books:

1. Copi, I. M., and Cohen, C. (2005). *Introduction to Logic*. 12th ed, Pearson Education.
2. Goodde, W.J. and Hatt, P.K. (1991). *Methods in Social Research*. International ed. McGraw-Hill Inc.,USA.
3. Ray, P.K. (2010). *A Textbook of Deductive Logic for the Use of Students*. Kessinger Publishing, LLC USA.
4. Skyrms, B. (2000). *Choice and Chance: An Introduction to Inductive Logic*. 4th edition. Thomson Learning, USA.
5. Salmon, M. H. (2006). *Introduction to Logic and Critical Thinking*. 5th edition. Wadsworth Publishing.
6. Hurley, P.J. (1988). "*A Concise Introduction to Logic*", 3rd Edition. Wadsworth Publishing Company.

STAT-713 Theory of Linear Models (3Cr.Hrs.)

Course Objectives:

- To provide sound knowledge of theory of standard statistical models and their properties
- To understand the theory of estimation and significance testing
- To be able critical understanding of model fitting

Intended Learning Outcomes:
Upon completion of this course the students will:

- A good understanding of the theory of standard statistical models, their properties and significance testing.
- Fit and fix random and mixed effect models.
- Carry out comparative analysis of various parameter estimation techniques.

Course Contents:
Introduction to linear models with examples, Review of Matrix Algebra, Generalized inverse, MLE, REML, Random vectors, multivariate normal distribution and quadratic forms, General linear model: Least Squares Estimation, Linear least squares problem, Best Linear Unbiased Estimation, Parameterization, Multivariate Normal Distribution of Quadratic Forms, Testing Linear Hypothesis, Simultaneous Confidence Intervals. Model fitting, extra sums of squares principle, Estimability, Testability. Model checking and model selection, Generalized least squares, Statistical inference for the general linear model, Sequential and hierarchical sums of squares, Sensitivity of assumptions in general linear model :Under-fitting, over-fitting, Fixed, random effect models.

Recommended Books:

1. Bingham, N. H., & Fry, J. M. (2010). Regression: Linear models in statistics. Springer Science & Business Media.
2. Graybill, F.A. (1976). *"Theory and Application of Linear Model"*, Duxbury, New York.
3. Michael, K., Nachtsheim, C., Neter, J., and Li, W. (2004) Applied Linear Statistical Model.: 5th edition. McGraw-Hill
4. Rencher, A. C., & Schaalje, G. B. (2008). Linear models in statistics. John Wiley & Sons.
5. Rao C. R., Toutenberg, H., Shalabh, and Heumann, C. (2007). Linear Models and Generalizations: Lest Squares and Alternatives. Springer.

STAT-714 Measure Theory (3Cr.Hrs.)

Objectives:

- To provide a more rigorous introduction to the theory of measure.
- Develop the ideas of Lebesgue integration and its properties.
- To develop understanding of the theory on empirical basis

Learning outcomes
Upon Successful completion of this course the students will:

- have an understanding of more sophisticated theory of integration and measure
- show that certain functions are measurable.
- construct the Lebesgue integral and understand properties of the Lebesgue integral;

Course Contents:
An overview of measure theory, Length of open and closed sets. Inner and outer measures. Properties of measurable sets. Measurable functions. Lebesgue integral and its properties for

bounded and unbounded measurable functions. Some fundamental theorems. Relationship of Riemann and Lebesgue integrals.

Recommended Books

1. Billingsley, Patrick (1986). *"Probability and Measure"*, 2nd Ed. John Wiley & Sons.
2. Burkill, C.J. (1971). *"The Lebesque Integral*", Cambridge University Press.
3. Goldberg, R.R. (1970). "*Methods of Real Analysis"*, Oxford and IBH Publishing Company.
4. Saxena,C.S. & Shah, S.M. (1980). *"Introduction to Real Variable Theory"*, Prentice-Hall of India (Pvt.), New Delhi.

STAT-715 Categorical Data Analysis (3Cr.Hrs.)

Course Objectives:

- To understand the basic concepts of categorical data analysis
- To recognize different types of categorical data and use appropriate methodology for categorical data
- To conduct statistical analysis using existing software and properly interpret the computer output.

Learning Outcomes:

- Implement basic categorical methods and combine them for the sampling estimation
- Obtain estimators, evaluate standard errors, construct confidence intervals and making statistical inference according to the categorical analysis techniques
- Apply the principles of lifelong learning to any new challenges arise with categorical data
- Demonstrate the knowledge to characterize, analyse and solve a wide range of problems related to the categorical data

Course Contents:

A brief overview of categorical data, contingency analysis, tables, Measures of association. Principles of likelihood-based inference. Maximum Likelihood Analysis for Frequency Data, Generalized Linear Models, Regression Type Models for Binomial and Poisson Data, Loglinear and Logit Models, Delta Method, Odd Ratio, Mantel-Haenszel Test, Iterative Weighted Least Squares and Maximum Likelihood, Analysis of Deviance and Residuals, Over dispersion, Underdispersion and Quasi likelihood Models, Log Linear Models for Multidimensional Contingency Tables.

Recommended Books:

1. Agresti, A. (2012). *Categorical Data Analysis.* 3rd edition. John Wiley & Sons.
2. Agresti, A. (2007). *An Introduction to Categorical Data Analysis*. 2nd edition. John Wiley & Sons.
3. Collett D. (2003). *Modeling Binary Data*. Champman and Hall/CRC.
4. Hosmer D. W. and Lemeshow S. (2004). *Applied Logistic Regression.* John Wiley & Sons.
5. Lloyd C. J. (1999). *Statistical Analysis of Categorical Data.* John Wiley & Sons.

6. Powers D. A. and Xie, Y. (2008). *Statistical Methods for Categorical Data Analysis.* 2nd edition. Emerald Group publishing.

STAT-716 Advanced Statistical Packages (Crdt.Hrs 3)

Course Objectives:

- To understand data analysis through various packages.
- To learn visualization of bench mark data sets through Minitab, SPSS and R.
- To acquire programming skills in R.

Learning Outcomes:

At the end of the course the students will be able to:

- Understand the data presentation, visualization and analysis using different packages.
- Perform programming in R for statistical data analysis.
- Describe and carry experiments in, various packages, on benchmark data sets.

Course Contents:

Introduction to R. Introduction to Variables, functions, control structures. Lists. Vectors. Indexing. Installation of packages. Matrices. Data frames. Importing data. Use of existing data sets in R. Conditions. Use of if then and "for loop". Drawing samples from various probability distributions. Data entry. Data processing. Data tabulation. Function arguments. Application of statistical tools in R. Graphics libraries. Simple plots. Customizing plots. Data splitting techniques. Acceptance sampling plans and control charts. Regression models, Normality checking methods, ANOVA and design of experiment. User interface (e.g. Rcmdr).
Python, MATLAB, SAS,

Recommended Books

1. John M. Chambers (1998) *Programming with Data*. Springer, New York. This is also called the "*Green Book*".
2. A. C. Davison and D. V. Hinkley (1997), *Bootstrap Methods and Their Applications*, Cambridge University Press.
3. Annette J. Dobson (1990), *An Introduction to Generalized Linear Models*, Chapman and Hall, London.
4. Peter McCullagh and John A. Nelder (1989), *Generalized Linear Models.* Second edition, Chapman and Hall, London.
5. John A. Rice (1995), *Mathematical Statistics and Data Analysis.* Second edition. Duxbury Press, Belmont, CA.
6. W. N. Venables, D. M. Smith and the R Core Team (2016): *Introduction to R.*

STAT-717 Economics for Statisticians (3 Cr.Hrs.)

Consumer Choice Theory: Individual decision making and preference structure, utility function, Budget constraint and consumer equilibrium, Deriving individual demand and discussion of its properties, Demand aggregation. Producer Theory: Production technology, iso-quant, iso-cost

curves, profit maximization and cost minimization, cost curves in short run and long run, Firm's input demand function. Market Structure and Firm's supply of output: Characteristics of perfect competition, Firm's supply under perfect competition, Monopoly, Firm's supply of output under monopoly, Price discrimination**.** National Income Accounts and Key Economic Indicators: Gross domestic product (GDP) and gross national product (GNP), Three approaches to measure GDP/GNP, Real and nominal GDP/GNP, Per capita GDP/GNP, GDP/GNP growth rates, Sectoral breakup of GDP/GNP, GDP deflator, Consumer Price Index (CPI) and inflation rate, Exchange rate, nominal and real exchange rate, bilateral and cross exchange rate, effective exchange rate, Balance of Payments (BOP) Accounts: current and capital account, Money: monetary base, broad monetary aggregates, balance sheet of central and commercial banks, Interest Rate: deposit rate, lending rate, monetary policy target interest rate, central bank repo rate, central bank reverse repo rate, interbank offered rate, Public Finance: budget deficit, fiscal deficit, primary fiscal deficit, current and development expenditure, direct and indirect taxes, Public Debt: floating debt, permanent debt, circular debt, productive debt, Savings: private saving, domestic saving, public saving, national saving, foreign saving, Investment: fixed investment, residential investment, inventories, depreciation. IS-LM Framework: Aggregate consumption function and saving behavior, Investment behavior, Money demand function, Money supply process, IS-LM model**.** AD – AS Framework: Deriving aggregate demand curve from IS-LM model, Labor demand and supply, Deriving aggregate supply curve from production function and labor market, Policy analysis in AD-AS model and Economic Schools of Thought**.** Economic Growth and Development: Solow growth model, Growth accounting, Stages and major theories of development**.** International Trade: Absolute and comparative advantage theories, Benefits of free trade, Trade policy instrument and their effectiveness, Political economy of trade policy. International Finance: Fixed and floating exchange rate systems, Exchange rate determination in market of foreign exchange, Policy analysis in different exchange rate regimes. Fiscal and Monetary Policy, Defining both policies, Objectives, targets, and instruments of both policies: open market operation, discount rate, reserve requirement, budget deficit and austerity measures

Recommended Books

1. Perloff, J. M. (2008). Microeconomics: theory and applications with calculus. *New Jersey, US: Pearson. Google Scholar*.
2. Abel, A. B., Bernanke, B., & Croushore, D. D. (2014). *Macroeconomics*. Pearson.
3. Paul R. Krugman, Maurice Obstfeld, and Marc J. Melitz (KOM). (2009). *International Economics: Theory and Policy*, 9th edition, Addison-Wesley.
4. Jones, C. (2014) *Macroeconomics*. 3rd Edition New York: W.W. Norton.
5. Todaro and Smith.(2015). *Economic Development*, 12th Edition, Addison-Wesley.

STAT-718 Advanced Statistical Inference (3Cr.Hrs.)

Course Objectives:

- To provide sound knowledge of theory of statistical inference.
- To enable the scholars to communicate the purposes of the analyses, the findings from the analysis, and the implications of those findings.
- To optimize the model fitting using various estimation techniques.

Learning Outcomes:

- Have a foundation for understanding probability-based statistical inference.
- Be able to apply various techniques to minimize variance and bias and have the knowledge of variance- bias tradeoff.
- Be able to apply parameter optimization algorithms for model fitting.

Course Contents:

Objective of statistical analysis and theory, criteria for the choice of families of models, the likelihood, sufficient statistics, some general principles of statistics inference, significance tests: discrete problems, composite alternatives, Local power, Multidimensional alternatives, composite null hypothesis, similar Region, invariants tests, Distribution–free and randomization tests: permutation tests, Rank test, Randomization tests, distance tests, Interval estimation: Scalar parameter, scalar parameter with nuisance parameters, Vector parameter, confidence region, Point estimation: General considerations on bias and variance, Cramer–Rao inequality, Achievement of minimum variance and remove of bias, estimates of minimum mean squared error, Robust estimation, Asymptotic theory: Introduction, maximum likelihood estimates, large sample parametric significance tests, Robust inference for location parameters.

Recommended Books:

1. Hogg, R., Elliot A. Tanis, Robert V. Elliot. (2000). *Probability and Statistical Inference.* Prentice Hall (6th Edition).
2. Lehmann, E.L. (1997). *Testing Statistical Hypotheses*. Springler - Valag, New York.
3. Lindgren, B.W. (1998). *Statistical Theory.* Chapman and Hall, New York.
4. Mood, A.M. Graybill, F.A. and Boss, D.C. (1997). *Introduction to the Theory of Statistics.* McGraw-Hill, New York.
5. Rao, C.R., (1973). Linear *Statistical Inference and its Applications.* John Wiley, New York.
6. Silvey, S. D. (1975). *Statistical Inference*. Chapman and Hall.

STAT-719 Advanced Regression Analysis (3Cr.Hrs.)

Course Objectives:

- To provide advanced knowledge on multiple regression and robust regression
- To understanding and application of model selection techniques
- To understand the concept of resampling techniques

Learning Outcomes:

- To compute and interpret the results of multivariate regression analysis
- To carry out analysis of residual and perform diagnostic tests
- To perform bootstrapping and cross validation
- To carry out model selection using backward, forward and stepwise selection approaches

Course Contents:

Brief review of multiple regression by least-squares, Outliers: Analysis of residuals, Influence measure, identifying influential observations, Diagnostics Tests, Robust regression, Tests for normality, choosing a regression model using various computational techniques: All possible regressions, forward selection, backward elimination and stepwise regressions. Re-Sampling techniques: Jackknifing, bootstrapping and cross-validation.

Recommended Books:

1. Belsley, D. A., Kuh, E., & Welsch, R. E. (2005). *Regression diagnostics: Identifying influential data and sources of collinearity*. John Wiley & Sons.
2. Draper, N. R., & Smith, H. (2014). *Applied regression analysis*(Vol. 326). John Wiley & Sons.
3. Kleinbaum, D. G., Kupper, L. L., Nizam, A., & Rosenberg, E. S. (2013). *Applied regression analysis and other multivariable methods.* Cengage Learning.
4. Rousseeuw, P. J., & Leroy, A. M. (2005). *Robust regression and outlier detection* (Vol. 589). John Wiley & sons.
5. Wetherill, G. B. (1986). Regression Analysis with applications. John Wiley and Sons New York.

STAT-720 Applied Multivariate Analysis (3Cr.Hrs.)

Course Objectives:

- To impart the conceptual and advanced knowledge of multivariate data.
- To teach various advanced techniques to handle the challenges presented by these data.
- To develop sound knowledge of multivariate theories and its application in different fields.

Learning Outcomes:

- Understanding of the link between multivariate techniques and corresponding univariate techniques.
- Recognition of the variety of advanced multivariate techniques and their proficient applications.
- Development of the skill to summarize, analyze and interpret the multivariate data.

Course Contents:

Review of Multivariate Normal Distribution and Matrix Algebra Results. spectral decomposition, singular-value decomposition, Principal Components Analysis and their Sampling Properties, the Factor Model, Principal Factor Analysis, Maximum Likelihood Factor Loadings, Cluster Analysis, Visual Approaches to Finding a Partition, Hierarchical Methods, Distances and Similarities, Single-Link Clustering, Discriminant Analysis, Discrimination Under Estimation, Probabilities of Misclassification, Discarding of Variables, Canonical Correlations, Mathematical Development, Qualitative and Quantitative Data, Multidimensional Scaling, Measure of Similarity and Dis-Similarity, Classical Scaling, Ordinal Scaling. Cluster analysis, multidimensional scaling, classification and regression tree (CART), Path analysis. Multivariate linear model: multivariate regression, multivariate analysis of variance (MANOVA) and multivariate analysis of covariance (MANCOVA).

Recommended Books:

1. Anderson, T.W. (2003). An Introduction to Multivariate Statistical Analysis, John Wiley & Sons, New York, USA.
2. Johnson, R. A. and Wichern, D. W. (2007). Applied Multivariate Statistical Analysis, Prentice Hall, New York, USA.

3. Manly, B.F.J. (2004). Multivariate Statistical Methods: A Primer, Chapman and Hall/CRC, New York, USA.
4. Mardia, K. V., Kent, J. T. and Bibby, J. M. (1976). Multivariate Analysis, Academic Press, New York, USA.
5. Rencher, A.C. and Christensen, W.F. (2012). Methods of Multivariate Analysis, John Wiley & Sons, New York, USA.
6. Morrison, D.F. (1976). "Multivariate Statistical Methods", 2nd Edition. McGraw-Hill.

STAT-721 Applied Survival Data Analysis (3Cr.Hrs.)

Course Objectives:

- To introduce the basic concepts of survival models
- To learn how time dependent and independent models can be applied in various fields
- To learn the usage of appropriate statistical software for survival analysis

Learning Outcomes:

- Understand the basic concepts and ideas of survival models
- Derive properties and methods for various survival models
- Perform and interpret parametric and non-parametric survival models using an appropriate software
- Use of different statistical software and packages for application of survival techniques.

Course Contents:

Multi-parameter Analysis Using Large Sample Likelihood Methods for Response Time Data, Survival Function and Hazard Function, Multi-parameter Models, Re-parameterization and Regression-Type Models, Likelihood Functions for Censored Data, Kaplan-Meier (Product-Limit) Estimator, Testing Based on Maximum Likelihood Estimators, Likelihood Ratios, and Score Tests, Analysis of Grouped Data. Nonparametric Methods of Estimating Survival Functions. Parametric Survival Distributions and Their Applications. Tests of Goodness-of-Fit and Distribution Selection; Based on Asymptotic Likelihood Inferences, Tests for Appropriateness of a Family of Distributions, Distribution selection through BIC or AIC. Hollander and Proschan's Test for Appropriateness of a Given Distribution with Known Parameters. Parametric Methods for comparison of Survival Distributions; Log-Likelihood Ratio Test for comparison of Exponential Distributions, Weibull Distributions and Gamma Distributions. Parametric Methods for Regression Model Fitting and Identification of Prognostic Factors; Preliminary Examination of Data, General Structure of Parametric Regression Models and Their Asymptotic Likelihood Inference, Exponential AFT Model, Weibull AFT Model, Lognormal AFT Model, The Extended Generalized Gamma AFT Model, Log-Logistic AFT Model, Other Parametric Regression Models, Model Selection Methods. Identification of Prognostic Factors Related to Survival Time: Non-Proportional Hazards Mpdels. Use of statistical packages and R programming for Survival analysis.

Recommended Books:

1. Collet, D. (2014). Modelling Survival Data in Medical Research. 3rd edition, CRC Press, Taylor and Francis Group. Fl, USA.
2. Lee, E. T., and Wang, J. W. (2013). Statistical Methods for Survival Data Analysis. 4th edition, John Wiley & Sons, New Jersey, USA.
3. Kleinbaum, D.G., Klein, M. (2012). Survival Analysis: A self-learning text. 3rd edition. Springer, New York, NY, USA.
4. Aalen, O. O, Borgan, O. and Gjessing (2012). Survival and Event history analysis. Spring series, New York, NY, USA.
5. Machin, D., Cheung, Y. B., and Parmar, M. K. (2006). Survival Analysis: A practical approach. 2nd edition, John Wiley & Sons, Ltd. England, U.K.
6. Klein, J. P., and Moeschberger, M. L. (2003). Survival Analysis: Techniques for Censored and Truncated data. 2nd edition, Springer series, New York, NY, USA.

STAT-722 Applied Stochastic Models (3Cr.Hrs.)

Course Objectives:

- This course aims to provide an understanding of stochastic processes and the ability to analyze certain aspects of these processes.
- Accordingly, the course starts by reviewing probability theory, conditional probability, independence and certain properties of random variables, and continues by examining stationary processes and Ergodic theorem.
- Furthermore, Markov chains in discrete and continuous time as well as Poisson processes are investigated in detail.

Learning Outcomes:

- Define probability models, concept and properties of random variables, random processes, Markov processes and Markov chains,
- Explain properties and functions of random processes with stochastic mathematical models.
- Formulate discrete and continuous time random processes, stationary random processes.
- Devise solutions with probability models for Poisson processes, discrete and continuous time Markov chains.

Course Contents:

Probability Generating Functions, Compound Distributions, Simple Random Walk, Branching Processes, Markov Processes, Discrete and Continuous Time Markov Chains, Branching Processes, Poisson Processes, Imbedded Markov Chains, Birth-Death Process, Immigration and Immigration Processes, Immigration-Death-Processes, Queuing Theory, Renewal Processes, Markov Renewal Process, Ergodic Theorem, Gaussian Processes and Brownian Motion.

Recommended Books:

1. Cinlar, E. (2013). *Introduction to Stochastic Processes*, Dover Publications, New York, USA.
2. Feller, W. (2008). *An Introduction to Probability Theory and its Applications*, John Wiley & Sons, New York, USA.
3. Gallager, R.G. (2014). *Stochastic Processes: Theory for Applications*, Cambridge University Press, New York, USA.

4. Karlin, S.A. and Taylor H.M. (2011). *A first course in Stochastic Process*, Academic Press London, London, UK.
5. Ross, S. M. (2008). *Stochastic Process*, John Wiley & Sons, New York, USA.

STAT-723 Mathematical Modeling and Simulation (3Cr.Hrs.)

Course Objectives:

- To understand the mathematical models using simulation
- To understand the simulation approaches to problem solving, on a diverse variety of disciplines.
- To check the validity of models.

Learning Outcomes:

- Recognize the connections between simulated and real data.
- Familiar with a variety of simulated examples where mathematical models helps accurately explain physical phenomena.
- Able to independently expand their mathematical or statistical expertise when needed, or for interest's sake.

Course Contents:

Principles and Methodology for Simulation Modeling, Monte Carlo methods: Different methods of generating random numbers, generation of random variables, acceptance and rejection techniques from various distributions. Comparison of algorithms to generate random variables, generating random variables from failure rates. Generation from multinomial distribution/Monte Carlo integration, Gibbs sampling and other resampling techniques, Variance reduction techniques, Statistical Validation Technique.: importance sampling for integration, control and antithetic variables.

Recommended Books:

1. Kleijnen, J.P.C. (1974). "Statistical Techniques in Simulation", Marcel Dekker, New York.
2. Pritsker, A.A.B. (1984). "Introduction to Simulation & SIAM", Halsted Press, New York.
3. Ross, S.M. (1990). "A Course in Simulation", Macmillan, New York.
4. Daniel P. M, Maynard T. (2006). Mathematical Modeling and Computer Simulation, Thomson Brooks/Cole
5. Fishman, G.S. (1996). Monte Carlo: Concepts, Algorithms, and Applications. Springer.
8. Ross, S.M. (2002). Simulation, 3rd Edition. Academic Press.
9. Velten, K. (2009). Mathematical modeling and simulation. Wiley VCH, Germany.

STAT-724 Spatial Data Analysis (3Cr.Hrs.)

Course Objectives:

- To introduce the spatial statistics providing students with necessary back ground to investigate the geographically represented data.

- To develop a deeper understanding of the three main areas of spatial statistics: geostatistical data, lattice (areal) data and point patterns.
- To develop comprehension in the application of spatial autocorrelation in statistical modeling.
- To develop the perception and basic skills to apply spatial methods in their own research using statistical software and Geographical Information System (GIS).

Learning outcomes:

- Distinguish different types of spatial data and understand how spatial autocorrelation plays a role in statistical modeling.
- Read and discuss new methods in the spatial statistics literature based on an understanding of the basic spatial statistics approaches, principles and main assumptions.
- Determine which spatial methods to use in their own research and implement them.
- Use existing methods to investigate spatial autocorrelation in example data sets provided as exercises.

Course Contents:

Introduction to Spatial Statistics and Data Handling, Eigen function Analysis of Areal Unit Configuration, Spatial Autocorrelation and Spectral Analysis, Models of Spatial Autocorrelation, Higher Order Autoregressive Models, Relationship between Autoregressive and Spectral Models, Kriging.

Recommended Books:

1. Bartlett, M. (1975), Statistical Analysis of Spatial Pattern, Chapman and Hall, London.
2. Cressie, N. (1987), Statistics of Spatial Data, John Wiley and Sons.
3. Griffith, D. (1988), Advanced Spatial Statistics, Kluwer, Bostan.
4. Ripley, B. (1988), Statistical Inference for Spatial Processes, John Wiley and Sons.
5. Upton, G. and Fingleton, B. (1985), Spatial Data Analysis by Example, Vol.1 & 2, John Wiley and Sons.
6. Fischer, M. M., & Wang, J. (2011). *Spatial data analysis: models, methods and techniques*. Springer Science & Business Media.

STAT-725 Applied Operations Research (3Cr.Hrs.)

Course Objectives:

- To introduce students to the advanced techniques of operations research.
- To provide students with skills of simulation and advanced modeling in Operations Research.
- To introduce students to practical application of operations research with emphasis on the industrial data.
- To effectively use relevant statistical software for data analysis.

Learning Outcomes:

- Identify and develop advanced operations research models from the verbal description of the real system
- Understand the mathematical tools that are needed to solve optimization problems
- Apply operations research techniques to summarize the industrial data
- Demonstrate the usage of statistical software for solving problem and analysing the relevant data

Course Contents:

History and definition of Operations Research (OR), nature and scope, Objectives, Major phases Types of models in OR. Mathematical and descriptive models, Static and Dynamic models, Formulation of model, major elements of a model, deriving solution for OR model. Testing the validity of the model and its implementation, examples of OR in business, industry. Introduction to linear programming model (LPM), properties, formulation, standard form, assumptions for LPM, Graphical method for solving LPM, solutions, Idea of Simplex method, Maximization and Minimization. Big-M method, Two-phase method, Duality problem and its solution. Introduction to Transportation model, comparison between LPM and transportation model, feasible solution by North-west corner method, Least-cost cell method, Vogel's approximation method, least time model, Sensitivity analysis of transportation model, Assignment model. Replacement models, failure mechanism of items, bath-tub curve, General approach for the solution of replacement problem, mortality tables. Introduction to integer programming, formulation of integer programming model, branch and bound method, advanced programming. Introduction to Queuing model, elements queuing system, Input process, service mechanism, distributional of arrival and service time. Classification of decisions, steps in decision theory approach, decision making under uncertainity and risk. Criterion of optimism, pessimism, Hurwicz criterion, regret criterion, Decision making with and without experimentation. Baye's decision rule, decision trees. Introduction to simulation, advantages of simulation, types, Monte Carlo simulation, Generation of random numbers. R programming for Operations Research study.

Recommended Books:

1. Taha, H.A. (2010). *Operations Research*. 9th edition, Pearsons.
2. Gupta, P. K. and Hira D. S. (2015) , *Operations Research*. 5th edition, S. Chand Publications, New Delhi
3. Murthy, P.R. (2007). *Operations Research*. 2nd edition, New age international publishers, New Delhi.
4. Daniel, P., Hayman, D. P. and Sobel, H.M.J. (2003). *Stochastic Models in Operations Research*. vol.1 and 2. Dover Publication.
5. Mehdi, J. (1985). *Stochastic Process*. Wiley Eastern Limited New Delhi.
6. Ross, S. M. (2004). *Stochastic Processes*. John Wiley & sons, Inc.

STAT-726 Advanced Statistical Methods Quality Control (3Cr.Hrs.)

Course Objectives:

- To provide a conceptual and practical knowledge of techniques for quality control.
- To provide the knowledge and techniques required to improve product quality and process efficiency by identifying and measuring production process variability.
- To determine most appropriate sample size needed to accept or reject a lot of material.
- To monitor the process control via control charts.

Learning Outcomes:

- Skill to draw various types of graphs to be used to monitor the industrial process.
- Awareness of design attribute and variable acceptance sampling plans for the industrial purpose.
- Ability to construct various types of attribute and variable sampling plans using statistical software.

- Proficiency to draw attribute and variable control charts to be implemented in different scenarios existing in industry.

Course Contents:
Statistical Process Control (SQC), Concepts of Process and Product, Quality of Design, Quality of Conformance, Dimensions of Quality, Importance of SQC in Industry, Acceptance Sampling Plans: Classification of plans (attribute and variable), Types such as Single, Double and Multi-stage sampling plans. Repetitive and multiple dependent state sampling (MDS) plans. Mixed Sampling plans. Control Charts based on Variable and Attribute quality characteristic, Control charts based on EWMA statistic, Process capability Indices Cp, Cpk, Cpm. Six Sigma: Historical Developments, DMAIC principles. Use of various probability distributions in the development of sampling plans and control charts. Optimization procedures and Simulation runs to find plan parameters of sampling plans and average run length in control charts. Friedman test to compare efficiency of sampling plans.

Recommended Books

1. Douglas C. Montgomery. (1996). *"Introduction to Statistical Quality Control"*, 3rd Edition, John Wiley & Sons, Inc.
2. Juran, J.M. and Godfrey, A.B. (1998). *Juan's Quality Control Handbook*, McGraw Hill, New York, USA.
3. Montgomery, D.C. (2013). *Introduction to Statistical Quality Control*, McGraw Hill, New York, USA.
4. Ryan, T.P. (2011). *Statistical Methods for Quality Improvement.* John Wiley & Sons, New York, USA.
5. Schilling, E.G. and Neubauer, D.V. (2008). *Acceptance Sampling in Quality Control*. Chapman & Hall, New York, USA.
6. Vardeman, S.B. and Jobe, J.M. (2016). *Statistical Methods for Quality Assurance: Basics, Measurement, Control, Capability, and Improvement*. Springer, New York, USA.

STAT-727 Time Series Analysis and Forecasting (3Cr.Hrs.)

Course Objectives:
- The objective of this course is to equip students with various forecasting techniques and knowledge on modern statistical methods for analyzing time series data.
- To make the students learnt the theory and application of the three parts: I. Univariate methods; II. Regression methods; III. ARIMA models.

Learning Outcomes:
- The ability to demonstrate an understanding of the principles behind modern forecasting techniques.
- The ability to select an appropriate model, to fit parameter values, and to carry out the forecasting calculation.

Course Contents:

Types of data, components of time series data, Stochastic processes, Stationary and non-stationary processes, Forms and tests of non-stationarity, Purely random processes, Random walk models, Lag operator, Difference equations and their solutions, Smoothing and decomposition methods, Univariate time series analysis (ARMA, ARIMA, Box-Jenkins approach, ARCH,GARCH etc.), Time series modeling and diagnostic checking, State space models and use of Kalman filter, Multivariate time series analysis: Granger causality, Vector Autoregressive Models. Transfer function and intervention analysis, Time series forecasting, Co-integration analysis, Vector error correction model and Johansen approach.

Recommended Books:

1. Anderson, T. W. (2011). *The statistical analysis of time series* (Vol. 19). John Wiley & Sons..
2. Box, G.E.P. and Jenkins G.M., Time-Series Analysis: Forecasting and Control 3rd Ed., Prentice Hall, Englewood Cliffs, N.J. USA, (1994).
3. Chatfield C. (2003) The Analysis of Time Series-An introduction. Tylor & Francis, NY, USA.
4. Jonathan D. C. and Kung-Sik C. (2008): Time Series Analysis with Applications in R, Springer, USA.
5. Lutkepohl, H. and Markus Kratzig (2004), Applied Time Series Econometric, Cambridge University Press, New York.
6. Peter J. B and Richard A. D (2002): Introduction to Time Series and Forecasting, Second Edition, Springer, USA.

STAT- 728 Classification and Regression Trees (3Cr.Hours)

Course Objectives:

- To explain and differentiate classification and regression methods.
- To teach the applications of decision tree techniques in classification of data.
- To study tree growing, pruning and generating strategy.

Learning Outcomes:

- Ability to distinguish between classification and regression methods.
- Use of some suitable software e.g. (SPSS, R, CART, WEKA) for classification of data.
- Understanding of the flow of the decision trees and the application of the decision tree techniques.

Course Contents:

Classification, classifier and an overview of classification techniques, Difference between supervised and un-supervised learning/classifiers, Decision trees and their generation procedures (tree growing process), role of evaluation functions to split parent node into two sub-nodes, Various node splitting evaluation functions (impurity-based and non-impurity-based) including Gini index, Towing rule and Entropy function. Properties of impurity-based evaluation functions, Selection criterion to split a node, Estimation of error rates and right sized classification trees. Construction of classification trees; evaluating the performance of a classifier: Holdout Method, Random Sub-Sampling, Cross-Validation and Bootstrap Samples.

Recommended Books:

1. Andrew, R. W. (2002). Statistical Pattern Recognition. Second edition. John Willey & Sons Ltd. UK.
2. Bramer, M. (2007). Principles of Data Mining. Springer-Verlag London Limited UK,.

3. Breiman, L., Friedman, J. H., Olshen, R. A. & Stone, C. J. (1984). Classification and Regression Trees. Wadsworth International Group, Belmont, CA.
4. Efron, B. & Tibshirani, R. J. (1993). An Introduction to the Bootstrap. Chapman and Hall, London, UK.
5. Rao, C. R., Wegman, E. J. & Solka, J. L. (2005). Handbook of Statistics, Vol. 24: Data mining and data visualization. Elsevier B.V., North Holland.
6. Tan, P., Steinbach, M. & Kumar, V. (2006). Introduction to Data Mining. Addison Wesley, New York.

STAT-729 Applied Biostatistics (3Cr.Hrs.)

Course Objectives:

- Empirical estimation of different types of data arising in Biological Sciences
- To use statistical techniques to summarize the Biological data
- To apply statistical software to analyze and evaluate Biological data

Learning Outcomes:

After completion of this course the students will be able to:

- Understand the applications of statistical tools in biological science.
- Demonstrate an understanding of the central concepts of modern statistical theory in Biological Sciences.
- Understand the appropriate usage of software for Biological sciences.
- Analyse and communicate the results of statistical analysis accurately and effectively.

Course Contents:

Applied statistical inference theory including parameter estimation, regression analysis and parametric and non-parametric hypothesis testing. Regression. Performance measurements such as sensitivity, specificity, positive predictive value. Bayesian inference. Orientating introduction to multivariate data analysis in the form of e g hierarchical cluster analysis and multivariate regression. Three way tables, rxc test for independence, Simpson's paradox, Confounding, G-Test. Proportions, rates and ratios; incidence, prevalence, Odds Ratio, Relative Risk, Rate Ratio, Sensitivity and specificity. Distributional behavior of biological variables (Binomial, Poisson and Normal), Role of transformation for analysis of biological variables, Probit and Logit transformations and their analysis. Prospective and Retrospective data. Experimental and observational study. Sampling design for epidemiological studies. Binary logistic regression, Multiple Logistic Regression. Proportional Hazard Model.

Recommended Books

1. Sullivan, M.L. (2018). *Essentials of Biostatistics in Public*. *Principles and Practice of Biostatistics*. 1st edition. Elsevier, India.
2. Alfassi Z. B., Boger, Z. and Ronen, Y. (2005): *Statistical Treatment of Analytical Data*. Blackwell Science, USA.
3. Daniel, W.W. (2010). *Biostatistics: A Foundation for the Health Sciences*. 6th edition. John Wiley, New York. NY, USA.
4. Zar, J. (2000). *Biostatistical Analysis.* 5th Edition. John Wiley & Sons, New York, NY, USA.
5. Woodward, M. (1999). "*Epidemiology; study design and data analysis*". Chapman and Hall, London.

6. Shoukri, M. M & Pause, C. A. (1998). "*Statistical Methods for Health Sciences*". 2nd Edition, CRC Press, Florida.
7. Daniel, W.W. (1996). "*Biostatistics: A Foundation for the Health Sciences*", 6th Edition, John Wiley, New York.

STAT-730 Statistical Consulting and Communication (3Cr.Hrs.)

Introduction to Statistical Consulting and Communication: What is Statistical Consulting? Roles of a Statistical Consultant. The Ideal Statistical Consultant and Satisfied Client: The Statistician's Perspective, The Client's Expectations, Aligning Expectations. The First Consulting Session: The impact of non-verbal communication, Creating good first impressions across cultures, Introducing the consultant to the problem, What is expected from the statistician? Asking Good Questions. Remaining Consulting Sessions: Effective communication of technical results to non-statisticians, Long term consulting projects. Dealing with Difficult Situations: The importance of communication, Conflict resolution, Ethical issues in statistical consulting. Oral Presentations: Identifying your audience and purpose, Methods for presenting technical statistical content to non-statisticians.

Recommended Books

1. Boen, J.R. and Zahn, D.A. (1982). The Human Side of Statistical Consulting. Lifetime Learning Publications, London.
2. Cabrera J. and McDougall, A. (2002). Statistical Consulting. Springer, New York
3. Chatfield, C. (1995). Problem Solving: A Statistician's Guide. 2nd Edition.Chapman & Hall, London
4. Derr. J. (2000). Statistical Consulting: A Guide to Effective Communication. Duxbury.
5. Hand, D.J. and Everitt, B.S. (Eds) (2012). The Statistical Consultant in Action. Cambridge University Press, Cambridge.
6. Rustagi, J.S. and Wolfe, D.A. (1982). Teaching of Statistics and Statistical Consulting. Academic Press, New York.

STAT-731 Demographic Methods (3Cr.Hrs.)

Introduction to Demography, Origin of Demographic data collection, Sources of demographic data, Population accounting and growth, Age/sex structures, The principles of the Lexis chart, Concepts and measurement of mortality, fertility and migration, Standardisation, Period-cohort measures, Life tables and their role in policy making and planning, Methods for making population estimates, Analytical methods for measuring components of population change from censuses and vital registration data as well as surveys. Population distribution, World demographic indicators, Anthropometric measures, Future population prospects.

Recommended Books

1. Hinde, A. (2014). *Demographic methods*. Routledge.
2. Parkin, T. G. (1992). *Demography and Roman society* (pp. 162-n). Baltimore, MD: Johns Hopkins University Press.
3. Preston, S., Heuveline, P. and Guillot, M. (2001). Demography: Measuring and modelling population processes.
4. Rowland, D.T. (2003). Demographic methods and concepts.

5. Siegel, J.S. (2002). Applied Demography: applications to business, government, law and public policy.

STAT-732 Meta Analysis (3Cr.Hrs.)

Course Objectives:

- To understand basic and advanced methods for meta-analysis with particular emphasis on using the statistical software R for conducting the analyses.
- Use of statistical programming in R for conducting the analyses.
- To understand the systematic review of observational studies based on meta-analysis

Learning Outcomes:

- To learn important aspects of a systematic review
- To learn a systematic review of observational studies based on meta-analysis
- To have an understanding of standard meta-analytic techniques and methodology

Course Contents:

Concept of meta-analysis, systematic reviews and meta-analyses, Systematic review process, diagnostic tests and accuracy, Fixed and Random Effects in Meta-Analysis, Differences in Treatment Effects in Meta-Analysis, Forest plots, Funnel plots. Heterogeneity and meta-regression, Power analysis for Meta-Analysis, Meta-Analysis methods based on p-values, Publication bias, Network meta-analysis and reporting a systematic review.

Recommended Books:

1. Julian, H. and Sally, G. (2008). Cochrane *Handbook for Systematic Reviews of Intervention.* 1st ed. John Wiley and Sons, New York.
2. Michael, B. Larry, H. Julian, H. and Hannah, R. (2009). *Introduction to Meta-analysis.* 1st ed., John Wiley and Sons, New York.
3. Matthias, E. George, D. Smith, and Doug A. (2001). *Systematic Reviews in Health Care: Meta-analysis in Context.* 2nd ed., BMJ Publishing Group, London.
4. Tom, P. and Jonathan, S. (2016). *Meta-analysis in Stata.* 2nd ed., Stata Press, USA

STAT-733 Social Network Analysis (3Cr.Hrs.)

Introduction to Social Network Analysis and its Applications, Types and Sources of Network Data, Representing Networks: Graphs and Matrices, Centrality and Centralization, Network Visualization; Introduction to Networks in R, Reciprocity, the Dyad Census, and an Introduction to Random Graphs, Transitivity, the Triad Census, and Conditional Uniform Graph Tests.
Positions, Roles, Block models, Homophily, Cohesive Subgroups, Graph Correlation, QAP, and Network Regression, Longitudinal Analysis of Social Networks, Introduction to Exponential Random Graph Models (ERGMs), ERGMs in practice, ERG Parametrization, Goodness of fit of ERGMs.

Recommended Books

1. Stephen Borgatti, Martin Everett and Jeffrey Johnson (2013). *Analyzing Social Networks*First Edition. Sage

2. John Scott (2000) *NetworkAnalysis: A Handbook*. Second Edition. Newbury Park CA: Sage.
3. Thomas Valente (2010). *Social Networks and Health: Models, Method sand Applications*, First Edition. Oxford University Press
4. Charles Kadushin (2011). *Understanding Social Networks: Theories, Concept sand Findings*, First Edition. Oxford University Press.
5. Stanley Wasserman and Katherine Faust (1994). *Social Network Analysis: Methods and Applications*. First Edition. Cambridge University Press.

STAT-734 Advance Experimental Design (3Cr.Hrs.)

Course Objectives:

- To provide the knowledge of advanced experimental designs and their uses in different disciplines.
- To provide basic and advanced skills of investigation for conclusions through planning and designing of experiments.
- To train students through innovative instruction in design theory and methodology that will help them in understanding the significance of experimental design in statistics and across the universal disciplines.

Learning Outcomes:

- Skill to encounter the principles of randomization, replication and blocking, and their application
- Ability to explore the general theory of complete and incomplete block designs and understand this theory sufficiently to find appropriate designs for specific applications
- Proficiency to evaluate designs using common optimality criteria and use them to critically compare competing designs
- Expertise in using statistical software to analyze common forms of experiments

Course Contents:

Resolution of the Factorial Experiments, Confounding and Fractionalization, Incomplete Block Design, Incidence Matrix, Lattice Design, Youden Squares, Split Plots, Strip Plots, Split-Split Plots, Strip-Split Plots, Response Surfaces, Change-Over Design, Repeated Measure, Analysis of Unbalanced Data. Incomplete block designs (IBD), balanced incomplete block designs (BIBD) and partially balanced incomplete block designs (PBIBD). Intra-block and Inter-block analysis of IBD. Resolvable block designs. Square lattice designs, rectangular lattice designs, generalized lattice designs. Latinized block designs, row-column designs, Latin square design. Factorial experiments: single and fractional replication. Response surface methodology, first and second order response surface designs. Optimal designs and optimality criteria, robust parameter designs and Taguchi methods.

Recommended Books:

1. Atkinson, A.C., Donev , A.N. and Tobias , R.D. (2007). *Optimum Experimental Designs, with SAS*. Oxford University Press, London, UK.

2. Box, G.E.P, Hunter, J.S. and Hunter, W.G. (2005) *Statistics for Experimenters: Design, Innovation and Discovery*. John Wiley & Sons, New York, USA.
3. Hinkelmann, K. and Kempthrone, O. (2005). *Design and Analysis of Experiment: 2nd Vol. Advanced Experimental Design*. John Wiley & Sons, New York, USA.
4. John, J.A. and Williams, E.R. (1995). *Cyclic and Computer Generated Designs*. Chapman and Hall/CRC, New York, USA.
5. Mead, R., Gilmour , S.G. and Mead, A. (2012). Statistical Principles for the Design of Experiments: Applications to Real Experiments. Cambridge University Press, London, USA.
6. Myers, H.R., Montgomery , D.C., Christine, M. and Cook , M. (2011). Response surface methodology: process and product optimization using designed experiments. John Wiley & Sons, New York, USA.

STAT- 735 Applied Smoothing Techniques (3Cr.Hours)

Course Objectives:

- This course provides a general class of techniques for nonparametric estimation of functions.
- Kernel smoothing is a nonparametric approach for estimating the relationship between a response variable and design variables. A major problem for kernel smoothing is the selection of the bandwidth, which controls the amount of smoothing.
- The selected topics for the study are helpful to meet the current research of interests in the field of nonparametric estimation.

Learning Outcomes:

- Transform set of irregular data points as a smooth line.
- Helpful in drawing inference about the nonparametric methods.
- Better understanding of these techniques and models involved in current research.

Course Contents:

Basic concepts of smoothing techniques. Univariate kernel density estimator, the MSE and MISE criteria. Order and asymptotic notation, Taylor expansion. Asymptotic MSE and MISE approximates, Exact MISE calculations. Canonical kernels and optimal kernel theory, Higher-order kernels. Local kernel density estimator, Variable kernel density estimator. Density derivation estimation, Bandwidth Selection. Quick and simple bandwidth selectors, Least square cross-validation and biased cross-validation. Plug-in bandwidth selection. Smoothed cross-validation bandwidth selection, Multivariate kernel density estimator and asymptotic MISE approximations. Bandwidth selection. Local polynomial kernel estimators, Asymptotic MSE approximation: linear case. Local polynomial kernel estimators. Multivariate nonparametric regression.

Recommended Books

1. Simonoff, J. S. (2010). Smoothing Methods in Statistics. Springer.
2. Wand, M. P. and Jones, M. C. (2012). Kernel Smoothing. Chapman and Hall.

3. Härdle, W. (2011). Applied Nonparametric Regression. Cambridge University Press.
4. Scott, D.W. (2015). Multivariate Density estimation: Theory, practice and visualization. Johan Wiley and Sons.
5. Schimek, M. G. (2012). Smoothing and Regression: Approaches, Computation and Application. Wiley series in Probability and Statistics.
6. Fan, J and Gijbels, I. (2013). Local Polynomial Modeling and its Applications: Monographs on Statistics and Applied Probability. CRC Press. USA.

STAT-736 Statistical Genetics (3Cr.Hours)

Course Objectives:

- To highlight the importance of Statistical genetics within the Life and Behavioural Sciences.
- The course is focused to provide an introduction to statistical methods for genetic studies.
- The contents has the sufficiency to obtain knowledge on statistical genetics and fathom skills to analyse data from human/animal and plant genetics.
- To introduce the Microarray Gene Expression data matrix and its evaluation relationship with applied multivariate techniques

Learning Outcomes:

At the end of this course the students will:

- The ability to evaluate conclusions that are based on genetic data.
- Insight into the mathematical, statistical, and computational basis of genetic analyses that use genome-scale data sets in systems biology settings.
- The study of Microarray Gene Expression data analysis will make the students meet the challenges of large complex data sets and be able to develop ability to contribute to new methodological and computational advances.

Course Contents:

Introduction to Genetics: Genome, Genome Type and Gene Expression , Of Wild-Types and Other Alleles, Aspects of underlying Biology and Physio-chemistry (DNA ,RNA and transcription). Introduction to Quantitative Genetics: Estimation of heritability, Quantitative trait Loci (QTLs),Genetic Correlations, Mendalein Disorder, Complex Traits.

General Concepts of Gene Mapping: Gene Frequency Estimation, Equilibrium , Linkages, Associations, Linkage disequilibrium, Markers Map. Microarray Gene Expression Data: Gene Expression Data Matrix, Screening and Unsupervised Classification (Clustering Analysis) of Gene Data, Supervised Classification of Tissue samples or Discriminant Analysis.

Analysis Microarray Genetic Data: Hand on practice on any two gene expression data sets available on different websites.

Recommended Books:

1. Gibson, G. (2009). Statistical Genetics: Gene Mapping Through Linkage and Association. *Genes, Brain and Behavior*, *8*(1), 127-128.
2. Laird, N. M., & Lange, C. (2010). *The fundamentals of modern statistical genetics*. Springer Science & Business Media.
3. Lin, S., & Zhao, H. (2010). *Handbook on Analyzing Human Genetic Data Computational Approaches and Software*. Springer-Verlag Berlin Heidelberg.
4. Laird, N. M., & Lange, C. (2010). *The fundamentals of modern statistical genetics*. Springer Science & Business Media.
5. McLachlan, G., Do, K. A., & Ambroise, C. (2005). *Analyzing microarray gene expression data* (Vol. 422). John Wiley & Sons.

6. Reilly, C. (2009). *Statistics in human genetics and molecular biology*. CRC Press.
7. Wu, R., Ma, C., & Casella, G. (2007). *Statistical genetics of quantitative traits: linkage, maps and QTL*. Springer Science & Business Media.

STAT- 737 Environmental Statistics (3Cr.Hours)

Course Objectives:

- To introduce the basic statistical methods necessary to conduct and understand statistical analyses of environmental issues and problems.
- To understand measurement, descriptive statistics, graphs, basic probability, correlation and regression.
- To have knowledge of inferential statistics (hypothesis testing, confidence interval construction, effect size calculation).

Learning Outcomes:

- Systematic advanced treatment of areas of current interest in the statistical theory and methods for environmental data.
- Application of statistical methods to important problems in environmental sciences, with a focus on understanding and quantifying change in environmental sciences or problems of this nature.
- Broad understanding of the conceptual underpinnings of statistics in ecology and conservation. The key distinctions among statistical methods commonly used in ecology and conservation.
- Become aware of a wide range of applications of statistics in environmental management, life sciences & decision making.

Course Contents:

The Role of Statistics in Environmental Science, Environmental sampling, Risk Analysis, Quintile Regression, Spatial Linear Regression, Sampling Methods, Stationary Processes, Auto-covariances and Spectral Analysis, Time Series Modeling and Forecasting, Autoregressive Moving Average (ARMA) processes, Statistical Monitoring Methods for Environmental System, Spatial Data Analysis, Censored Data, Change Point Analysis, Statistical Methods for non-stationarity.

Recommended Books:

1. Millard, S. P. (2013). EnvStats, an R Package for Environmental Statistics. John Wiley & Sons, Ltd.
2. Chandler, R., & Scott, M. (2011). Statistical methods for trend detection and analysis in the environmental sciences. John Wiley & Sons.
3. Manly, B. F. (2008). Statistics for environmental science and management. CRC Press.
4. Shaefer, S. J., & Theodore, L. (2007). Probability and statistics applications for environmental science. CRC Press.
5. Wikle, C. K. (2006). Environmental Statistics: Methods and Applications.
6. Barnett, V. (2005). Environmental statistics: methods and applications. John Wiley & Sons.
7. Ott, W. R. (1994). Environmental statistics and data analysis. CRC Press.

STAT- 738 Regression Models for Count Data (3Cr.Hours)

Course Objectives:

- To understand the count data exclusively other than categorical data.
- To learn the characteristics and existence form of count data in different fields.
- To enhance skills in comprehension and evaluation of statistical methods for count data.
- To learn and apply the various discrete and extended discrete probability distributions in real life count data.

Learning Outcomes:

- Acquire the mathematical basis of Count Regression models.
- Analyze data arising from observational studies.
- Understand the role of statistical modelling in discovering information, making predictions and decision making in a range of applications in distinct fields of natural and social science.

Course Contents:

Count data basics, Count Regression Models: Specification and estimation of count regression models, Poisson MLE, PMLE and GLM. Negative Binomial MLE QGPMLE, Over Dispersion Tests, Ordered Models.

Generalized Count Regression Models, Mixture models for unobserved heterogeneity, Models based on waiting time distributions, Katz, Poisson and Generalized Poisson, Truncated and Censored Counts, Hurdle and Zero-inflated models.

Model evaluation and Testing: Residual analysis, Goodness of fit, Hypothesis Tests.

Recommended Books:

1. Colin, A. C., & Trivedi, K. P. (2010). Micro-Econometrics Using Stata, Edition 2. Stata Press: Texas, USA .
2. Colin, A. C., & Trivedi, K. P. (2013). *Regression Analysis of Count Data*, 2nd Edition, Econometric Society Monograph, Cambridge University Press: Cambridge, UK. Econometrics, Volume V, North Holland, Amsterdam.
3. Hilbe, M. J. (2011). *Negative Binomial Regression. 2nd edition*, Cambridge University Press: Cambridge, UK.
4. Lancaster, T. (1990). *The Econometric Analysis of Transition Data*, Cambridge multiple durations, in J.J. Heckman and E. Leamer, editors, Handbook of University Press.
5. Winkelmann, R. (2010). Econometric Analysis of Count Data. Springer Verlag: Berlin Heidelberg.

STAT-739 Non-Linear Statistics (3Cr.Hrs.)

Models, Parameters and estimation using ML method, Transformations of parameters, inference and stable transformations. Computing Methods for Non-linear Modelling, Confidence intervals for parameters and functions. Applications of non-linear modelling.

Recommended Books

1. Ross, G. J. S. (1990). Non-linear Estimation, Springer-Verlag, New York Inc.
2. Seber, G. A. F. and Wild, C.J. (1989). Non-linear Regression, New York John Wiley.

3. Kotz, S. and Johnson, N. (1985). Encyclopaedia of Statistical Sciences (Non-linear Models, Non-Linear Regression) N.Y. Wiley.
4. Ralkowsky, D.A. (1984). Non-Linear Regression Modelling, Dekker New York.
5. Bard Y. (1974). Non-linear Parametric Estimation, Academic Press, New York.

STAT-740 Big Data Analysis (3Cr.Hrs.)

Overview of linear and logistic regression, model choice and false discovery rates, information criteria and cross validation, regularized regression and the lasso, bagging and the bootstrap, experiments and causal estimation, multinomial and binary regression, classification, latent variable models, principal component analysis, topic models, decision trees and random forests, text analysis and natural language processing.

Applications of Big Data Analytics: consumer database mining, internet and social media tracking, asset pricing, network analysis, sports analytics, and text mining.

Recommended Books

1. Baesens, B. (2014). *Analytics in a Big Data World: The Essential Guide to Data Science and its Applications*. John Wiley & Sons Inc., New Jersey.
2. Hurwitz, J., Nugent, A., Halper, F., and Kaufma, M. (2013). *Big data for Dummies*. John Wiley & Sons Inc., New Jersey.
3. Hastie, T., Tibshirani, R., and Friedman, J. (2009). *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*. 2nd Edition. Springer.
4. Mayer---Schonberger,V.andCukier,K.(2014).“*Big Data*”, Mariner Books, Boston, MA.
5. Provost,F. and Fawcett T. (2013). “*Data Science for Business*”, O’Rielly, Sebastopol, CA.

STAT-741 Application of Non-Parametric Techniques (3Cr.Hrs.)

Common non-parametric tests, Non-parametric analysis of variance, Non-parametric regression, robustness, breakdown and the influence cure, estimation using M-Statistics, L-Statistics and R Statistics, Contaminated distributions, Sampling-resampling Methods: Bootstrap and Jackknife. Confidence Intervals.

Recommended Books

1. Conover, W. J. (1999). Practical Nonparametric Statistics, 3rd Ed., John Wiley and Sons. New York.
2. Huber, P. (1987). Robust Statistical Procedures, Society for Industrial and Applied Mathematics.
3. Hampel, J. W., Robust Statistics: The Approach Based on Influence function, (1986).
4. Maritz, J. S. (1995). Distribution Free Statistical Methods, Chapman and Hall, London.
5. Gibbons, J. D. and Chakrabortic, S. (1992). Nonparametric Statistical Inference, Marcel Dekker, New York.
6. Rousseeuw, L. (1987). Robust Regression and Outlier Detection, John Wiley & Sons.
7. Randles, R. H. and Wolfe, D. A. (1979). Introduction to the Theory of Non-Parametric Statistics, John Wiley and sons.

STAT- 742 Machine Learning (3Cr.Hrs.)

Introduction: Overview of Supervised Learning. Linear Methods for Classification: Linear

Discriminant Analysis; Logistic Regression, Filtering and Feature Extraction. Model Assessment and Selection: Bias–Variance Trade off; Error Rate; Optimism of the Training Error Rate; Sensitivity; Specificity; Cross-Validation; Bootstrap Methods. Tree-Based Methods: Regression Trees; Classification Trees, Impurity Measures. Boosting: Boosting Trees. Support Vector Machines: Support Vector Machines for Regression and Classification. Nearest Neighbors: k-Nearest-Neighbor (k-NN) Classifiers; k-NN Regression. Ensemble Learning: Bagging; Bagging Tree Classifiers, Random Forests. The Curse of Dimensionality: Feature Selection. Application of the above, where possible, in any of R, SAS, MATLAB or C++.

Recommended Books

1. Bishop, C. (2006). Pattern Recognition and Machine Learning, Springer, New York
2. Breiman, L., Friedman, J., Olshen, R. and Stone, C. (1984). Classification and Regression Trees, Wadsworth, New York.
3. Duda, R., Hart, P. and Stork, D. (2000). Pattern Classification (2nd Edition), Wiley, New York.
4. Efron, B. and Tibshirani, R. (1993). An Introduction to the Bootstrap, Chapman and Hall, London.
5. James. G., Witten. D., Hastie. T., Tibshirani. R. (2013). An Introduction to Statistical Learning: with Applications in R. Springer-Verlag New York.
6. Marsland, M. (2009). Machine Learning: An Algorithmic Perspective, Chapman & Hall.
7. T. Hastie, R. Tibshirani, and J. Friedman (2009). The Elements of Statistical Learning. Springer series in statistics. Springer, New York.
8. Zhi-Hua Zhou. (2012). Ensemble Methods: Foundations and Algorithms (1st ed.). Chapman & Hall/CRC.

STAT-743 Pattern Recognition (3Cr.Hrs.)

This course covers the fundamentals of pattern recognition. The topics include pattern classification and regression, Bayes Decision Rule, Minimum Error Rate classification. Loss and risk function, discriminant functions, decision boundaries. Hidden Markov Models (HMM). Features extraction for classification, Dimensionality reduction.

Recommended Books

1. Duda, R. O., Hart, P. E., Stork, D. G. (2001). Pattern classification. 2nd. Edition. New York.
2. Bishop, C. M. (2006). Pattern recognition and machine learning. Springer-verlag New York. Inc. Secaucus, NJ, USA
3. Friedman, J., Hastie, T., Tibshirani, R. (2001). The elements of statistical Learning. New York, USA.

Ph.D. Statistics

List of the Courses

Course Code	Title	Credit Hours
STAT-811	Advanced Survival Data Analysis	3
STAT-812	Advanced Operations Research	3
STAT-813	Discrete Event Simulation	3
STAT-814	Computational Statistics	3
STAT-815	Robust Statistics	3
STAT-816	Advanced Econometrics	3
STAT-817	Generalized Linear Mixed Models	3
STAT-818	Advanced Statistical Theory	3
STAT-819	Statistical Methods for Clinical Trials	3
STAT-820	Longitudinal Data Analysis	3
STAT-821	Causal Inference	3
STAT-822	Performance Modeling	3
STAT-823	Statistical Signal Processing	3
STAT-824	Advanced Categorical Data Analysis	3
STAT-825	Recent Developments in Statistics	3
STAT-826	Multilevel Modeling	3
STAT-827	Structural Equation Models	3
STAT-828	Bayesian Statistical Techniques	3
STAT-829	Fuzzy Analysis	3
STAT-830	Data Mining	3
STAT-831	Randomized Response	3
STAT-832	Statistical Learning and Data Analytic	3
STAT-833	Financial Econometrics	3
STAT-834	Advanced Demographics Techniques	3
STAT-835	Advanced Multivariate Analysis	3
STAT-836	Exploratory Data Analysis and Visualization	3
STAT-837	Repeated Measure Analysis	3
STAT-838	Mixture Distributions	3
STAT-839	Ecological Statistics	3
STAT-840	Classification and Random Forecast Techniques	3
STAT-841	Item Response Theory	3
STAT-842	Advanced Machine Learning	3
STAT-843	Bio-Informatics	3

Details of the courses

STAT-811 Advanced Survival Data Analysis (3Cr.Hrs.)

Course Objectives:

- To introduce the basic concepts of survival models
- To learn how time dependent and independent models can be applied in various fields
- To learn the usage of appropriate statistical software for survival analysis

Learning Outcomes:

- Understand the basic concepts and ideas of survival models
- Derive properties and methods for various survival models
- Perform and interpret parametric and non-parametric survival models using an appropriate software
- Use of different statistical software and packages for application of survival techniques.

Course Contents:

Nonparametric Methods of Estimating Survival Functions; Product-Limit Estimates of Survivorship Function, Nelson–Aalen Estimates of Survivorship Function Life-Table Analysis, Relative Survival Rates, Standardized Rates and Ratios. Nonparametric Methods for Comparing Survival Distributions; Comparison of Two Survival Distributions, the Mantel and Haenszel Test, Comparison of K (K > 2) Samples. Parametric Survival Distributions and Their Applications; Exponential Distribution, Weibull Distribution, Lognormal Distribution, Gamma, Generalized Gamma, and Extended Generalized Gamma Distributions, Log-Logistic Distribution, Other Survival Distributions. Estimation Procedures for Parametric Survival Distributions without Covariates; General Maximum Likelihood Estimation Procedure for different distributions, Graphical Methods. Tests of Goodness-of-Fit and Distribution Selection; Goodness-of-Fit Test Statistics Based on Asymptotic Likelihood Inferences, Tests for Appropriateness of a Family of Distributions, Selection of a Distribution by Using BIC or AIC Procedure, Tests for a Specific Distribution with Known Parameter, Hollander and Proschan's Test for Appropriateness of a Given Distribution with Known Parameters. Parametric Methods for Comparing Two Survival Distributions, Parametric Methods for Regression Model Fitting and Identification of Prognostic Factors; Preliminary Examination of Data, General Structure of Parametric Regression Models and Their Asymptotic Likelihood Inference, Exponential AFT Model, Weibull AFT Model, Lognormal AFT Model, The Extended Generalized Gamma AFT Model, Log-Logistic AFT Model, Other Parametric Regression Models, Model Selection Methods. Identification of Prognostic Factors Related to Survival Time: Non-Proportional Hazards Models; Models with Time-Dependent Covariates, Stratified Proportional Hazards Model, Competing Risks Model, Recurrent Event Models, Models for Related Observations. Identification of Risk Factors Related to Dichotomous and Polychotomous Outcomes; Univariate Analysis, Logistic and Conditional Logistic Regression Model for Dichotomous Outcomes Models for Polychotomous Outcomes, Models for Related Observations. Use of statistical packages and R programming for Survival analysis.

Recommended Books

1. Collet, D. (2014). *Modelling Survival Data in Medical Research.* 3rd edition, CRC Press, Taylor and Francis Group. Fl, USA.
2. Lee, E. T., and Wang, J. W. (2013). *Statistical Methods for Survival Data Analysis.* 4th edition, John Wiley & Sons,New Jersey, USA.
3. Kleinbaum, D.G., Klein, M. (2012). *Survival Analysis: A self learning text.* 3rd edition. Springer, New York, NY, USA.
4. Aalen, O. O, Borgan, O. and Gjessing (2012). *Survival and Event history analysis*. Spring series, New York, NY, USA.
5. Machin, D., Cheung, Y. B., and Parmar, M. K. (2006). *Survival Analysis: A practical approach.* 2nd edition, John Wiley & Sons, Ltd. England, U.K.
6. Klein, J. P., and Moeschberger, M. L. (2003). *Survival Analysis: Techniques for Censored and Truncated data*. 2nd edition, Springer series, New York, NY, USA.

STAT-812 Advanced Operations Research (3Cr.Hrs.)

Course Objectives:

- To introduce students to the advanced techniques of operations research.
- To provide students with skills of simulation and advanced modeling in Operations Research.
- To introduce students to practical application of operations research with emphasis on the industrial data.
- To effectively use relevant statistical software for data analysis.

Learning Outcomes:

- Identify and develop advanced operations research models from the verbal description of the real system
- Understand the mathematical tools that are needed to solve optimization problems
- Apply operations research techniques to summarize the industrial data
- Demonstrate the usage of statistical software for solving problem and analysing the relevant data

Course Contents:

History and definition of Operations Research (OR), nature and scope of Operations Research, Objectives of OR, Major phases of OR study, Types of models in OR, Mathematical and descriptive models, Static and Dynamic models, how to formulate a model, major elements of a model, deriving solution for OR model, Testing the validity of the model and its implementation, examples of Operations Research in business, industry etc. Introduction to linear programming model (LPM), properties of LPM, formulation of LPM, standard form of a LPM, assumptions for LPM, Graphical method for solving LPM, , feasible and optimal solutions, Idea of Simplex method, Maximization and Minimization case, Big-M method, Two-phase method or Artificial variable method, Duality problem, primal-dual relationships, optimal solution to dual problem, dual simplex method, Sensitivity analysis. Introduction to Transportation model, comparison between LPM and transportation model, feasible solution by North-west corner method, Least-cost cell method, Vogel's approximation method, least time model, Sensitivity analysis of transportation model, Assignment model. Replacement models, failure mechanism of items, bath-tub curve, General approach for the solution of replacement problem, mortality tables. Introduction to Integer programming, formulation of integer programming model, branch and bound method, advanced programming, Either-Or constraints, If-Then constraints. Introduction to Queuing model, elements of a Queuing system or process, Input process, service mechanism, distributional of arrival and service time, birth-death process, single server model, multiple

server model. Introduction to Decision, classification of decisions, steps in decision theory approach, decision making under uncertainty, decision making under risk, criterion of optimism, criterion of pessimism, Hurwitz criterion, regret criterion, Decision making with and without experimentation, Bayes decision rule, decision trees Introduction to simulation, advantages of simulation, types of simulation models, Monte Carlo simulation, Generation of random numbers, Use of computer packages and R programming for Operations Research study.

Recommended Books

1. Gupta, P. K. and Hira D. S. (2015) , *Operations Research.* 5th edition, S. Chand Publications, New Delhi
2. Taha, H.A. (2010). *Operations Research*. 9th edition, Pearsons.
3. Murthy, P.R. (2007). *Operations Research*. 2nd edition, New age international publishers, New Delhi.
4. Daniel, P., Hayman, D. P. and Sobel, H.M.J. (2003). *Stochastic Models in Operations Research.* vol.1 and 2. Dover Publication.
5. Mehdi, J. (1985). *Stochastic Process.* Wiley Eastern Limited New Delhi.
6. Ross, S. M. (2004). *Stochastic Processes.* John Wiley & sons, Inc.

STAT-813 Discrete Event Simulation (3Cr.Hrs.)

Course Objectives:

- Overview over methods for discrete events simulation, as well as know of their strengths and weaknesses.
- Knowledge of some commonly used simulators / simulation tools.
- Knowledge of the basic elements of a discrete event simulator, specifically the handling of event.
- Knowledge of techniques to reduce variance and shorten the simulation times.
- Understanding the theoretical basis for these and the challenges of applying them. Firm knowledge of the planning of simulation studies and analysis of simulation results

Learning Outcomes:

Upon completions of this course the students will be able to:

- As a minimum, object-oriented simulation (prior knowledge required) and Markov simulation should be mastered.
- Set up and carry out simulation studies.
- Analyze simulation results applying adequate statistical methods.
- Have a firm understanding of the simulation with discrete events as an evaluation method in a broad context.

Course Contents:

Introduction: Modeling, Simulation. The Simulation Study, Workloads and Performance Metrics, Choice of Modeling Units and Time Scales, Documentation. Implementation: Simulation Software, Requirements of a General-Purpose Language, Modeling Approaches. Simulation Model Structure. Random Numbers: Randomness, Generating Random Numbers from Probability Distributions, Goodness of Fit, Selecting a Distribution. Entities and Resources: The Scheduler: The Job of the Scheduler, Types of Algorithm, Dynamic Algorithms, Performance Comparison, Implementation Simultaneous Events. Queues: The Structure of a

Queuing System, Basic Queuing Theory, the Implementation of Queues, Queues Behavior. Gathering Results: Recording Results, Measurements, Outputting Results. Results Analysis: The Dynamic Behavior of Simulation Models, Transient Effects, Detection of the Steady State, Estimating Accuracy, Realizing Accuracy Goals, Analysis of Transient Behavior.

Recommended Books

1. Mihram, G.A. (1972). "Simulation: Statistical Foundations and Methodology", London.
2. Pidd, MC (1989). "Computer Modeling for Discrete Simulations", U.K.
3. Walking, K. (1993). "Discrete Event Simulation in C".
4. Daniel P. M, Maynard T. (2006). Mathematical Modeling and Computer Simulation, Thomson Brooks/Cole
5. Fishman, G.S. (1996). Monte Carlo: Concepts, Algorithms, and Applications. Springer.
6. Ross, S.M. (2002). Simulation, 3rd Edition. Academic Press.

STAT-814 Computational Statistics (3Cr.Hrs.)

Recurrence Relations: Binomial Coefficients, Horner's Methods, Sample Means & Variances, Poisson-Binomial Distribution, an Unstable Recurrence. Power Series Expansion: Expansion of $P(s)^n$, Expansion of $e^{p(s)}$, Standard Normal Distribution, Incomplete Gamma and Beta Functions, Connections to other Distribution (x^2, Standard Normal, Poisson, Binomial F, Student's –T etc.,). Continued Fraction Expansion: Wallis Algorithms, Equivalence Transformation, Gauss's Expansion of Hyper Geometric Function. Asymptotic Expansion: Finite Taylor Expansions, Expansions Via Integration by Parts, General Definition of an Asymptotic Expansion, Laplace's Method and its Validations. Solution of Nonlinear Equations. Linear Regression and Matrix Inversion. Eigen Values and Eigen Vectors. Splines. The EM Algorithms. Newton's Method and Scoring. Convergence of Optimization Algorithms.

Recommended Books

1. Haimmerlin, G. Hoffmann K-H. (1991). *"Numerical Mathematics"*, Springer-Verlag, New York.
2. Henrici, P. (1982). "*Essential of Numerical Analysis with Pockit Calculator Demonstrations "*, Wiley New York.
3. Kenneth, L. (1998). *"Numerical Analysis for Statistician*", Springer-Veriag New York.
4. Wilf, H.S. (1986). *"Algorithms and Complexity*", Prentice Hall, New York

STAT-815 Robust Statistics (3Cr.Hrs.)

Course Objectives:

- The objectives of this course is to provide an introduction to both basic and advanced analytical tools for robust models. This course also aims to promote a critical perspective on the use of statistical informations.
- Beginning with simple statistical methods, the course builds to more robust analytical techniques such as multivariate linear regression and estimators.
- Emphasis is placed on theoretical understanding of concepts as well as the application of key methodologies used in different research fields.

Learning Outcomes:

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

- Explain the importance, techniques and biases of estimators in context
- Explain the concept of outliers in regression model and other influential observations
- Construct and interpret various statistical hypothesis tests.

Course Contents:

Introduction to Robust Statistics; the Aims of Robust Statistics, the Main Approaches towards a Theory of Robustness, Objective function, M-estimator of location, E-estimator, R-estimator and W-estimator, Redescending M-estimator's The Breakdown point of Robust estimator. The Influence Function and Breakdown Bound; Classes of Estimators: M-Estimators, L-Estimators, W-Estimators, R-Estimators, P-Estimators and S-Estimators; LMS, LTS, LTA; Robustness Properties in Linear Models; Robustness Testing in Linear Models. M-estimator for scale, Jackknife Resampling, Outliers and influential observations, Outliers in Regression analysis

Recommended Books:

1. Hamper, T.R. Brochette, E. M., Rousseau, P.J. and Satchel, W.A. (1986). Robust Statistics: The approach Based on Influence functions, John Wiley & Sons, New York, USA.
2. Hosmer, D.W. and Lemeshow, S. (2008). Applied Survival Analysis, John Wiley & Sons, New York, USA.
3. Huber, P. J. and Ronchetti, E.M. (2009). Robust Statistics, John Wiley & Sons, New York, USA.
4. Maronna, R.A., Martin, D.R. and Yohai, V.J. (2006). Robust Statistics: Theory and Methods, John Wiley & Sons, New York, USA.
5. Rousseau, P.J. and Leroy, A.M. (1987). Robust Regression and outlier detection, John Wiley & Sons, New York, USA.

STAT-816 Advanced Econometrics (3Cr.Hrs.)

Simultaneous-Equation Models, Methods of Identification, Methods of Estimation, Finite and Infinite Distributed Lag Models, Serial-Correlation Problems, Seasonality, Aggregation Over Time, Computation Of Mean Lags, Weak Parametric Specifications, The Almon Distributed Lag, Shiller's Method and Ridge Estimators, Varying Parameter Models, A Model of Systematically Varying Parameters, Hildreth and Houck Models, Switching Regression Model, Adaptive Regression Models, Stochastically Convergent Parameter Models, Kalman-Filter Models, Random Coefficient Models, Mixed Estimation Methods, Restricted Least-Square,

Pooling Cross-Selection and Time-Series Data, Forecasting With A Single-Equation Regression Model, Forecasting With A Multi-Equation Econometric Model, Evaluation of the Forecasting Power, Ranking of the Econometric Technique.

Recommended Books

1. Desai, M. (1977). *"Applied Econometrics"*, Philip Allen Publishers Limited, Oxford.
2. Green, W.H. (1991). *"Econometric Analysis*", McMillan Publishing Company New York.
3. Gujrati, D. (1983). *"Basic Econometrics*", McGraw-Hill Kogakussa Company, Singapore.
4. Johnston, J. (1984). *"Econometric Methods*", McGraw-Hill Book Company, Singapore.
5. Judge, G.G. (1985). *"The Theory and Practice of Econometrics"*, 2nd Edition. John Wiley & Sons.
6. Maddala, G.S. (1977). "*Econometrics"*, McGraw-Hill Inc.
7. Pakorny, M. (1987). "*An Introduction to Econometrics"*, Basil Blackwell Ltd.

STAT-817 Generalized Linear Mixed Models (3Cr.Hrs.)

Course Objectives:

- To provide the basic tools to use linear, generalized, linear mixed and generalized linear mixed models and focuses on understanding the unified theoretical basis for the using GLMM.
- To teach standard linear models, GLMMs and the models beyond GLMMs.
- To educate on the use of statistical software to model GLMMs.

Learning Outcomes:

After completion of this course the students will be able to:

- Command on the application of classic statistical models for dependent responses based on random components, including: linear, generalized, linear mixed and generalized linear mixed models.
- Identification of pertinent models for answering the biologic/scientific question of interest
- Identification of the key assumptions related to those statistical models
- Conduction of the analysis using statistical software and drawing conclusions

Course Contents:

Review of linear model (LM); model development; estimation of LM parameters through least squares (LS), generalized least squares (GLS), maximum likelihood (ML) and restricted maximum likelihood (REML); distributional properties in LM; development of test statistics and statistical inference in LM; Introduction to generalized linear model (GLM); components of GLM; properties, score function, hessian matrix and information matrix of exponential family of distributions; estimation of GLM parameters and statistical inference; Introduction to Linear Mixed Model (LLM); estimation of fixed effects and variance components; prediction of random effects; statistical inference in LLM; Introduction to generalized linear mixed model (GLMM);

estimation of fixed effects and variance components; prediction of random effects and statistical inference in GLMM.

Recommended Books:

1. Demidenko, E. (2004). Mixed Models: Theory and Applications, John Wiley & Sons, New York, USA.
2. McCulloch, C.E., Searle, S.R. and Neuhaus, J. M. (2008). Generalized, Linear, and Mixed Models, John Wiley & Sons, New York, USA.
3. Searle, S.R. (1997). Linear Models, John Wiley & Sons, New York, USA.
4. Searle, S.R., Casela, G., and McCulloch, C.E. (1992). Variance Components, John Wiley and Sons, New York, USA.
5. Stroup, W.W. (2012). Generalized Linear Mixed Models: Modern Concepts, Methods and Applications, Chapman and Hall/CRC, New York, USA.
6. Verbeke, G. and Molenberghs, G. (2000). Linear Mixed Models for Longitudinal Data, Springer, New York, USA.

STAT-818 Advanced Statistical Theory (3Cr.Hrs.)

Probability Measures, Expectations, Conditioning, Convergence of Random Sequence, Law of Large Numbers, Central Limit Theory, Characteristic Functions, Discrete Distributions, Continuous Distributions, Pearson Systems of Distributions, Chebyshev-Hermite Polynomials, Gram-Charlier Series (Type-A), Polynomial Transformations to Normality, Order Statistics and Their Sampling Characteristics, Distributions of Extreme Values, Non-Central Chi-Square, t and F Distributions.

Recommended Books

1. Billingsley, P. (1986). *"Probability and Measure*", 2nd Edition, John Wiley & Sons.
2. Johnson, N.L. and Kota, S. (1970). *"Continuous Univariate Distributions",* Vol-1, 2, John Wiley & Sons.
3. Stuart, A and Ord, J.K. (1987). *"Kendall's Advance Theory of Statistics: Distribution Theory",* Vol- I, 5th Edition, Charles Griffin and Co. Ltd.

STAT-819 Statistical Methods for Clinical Trials (3Cr.Hrs.)

Course Objectives:

- To enhance the students' awareness and informed usage of modern methods in the design and analysis of randomized control trials.
- To improve statistical thinking as applied to clinical research.
- To provide a foundation for research in statistical methods for clinical trials.

Learning Outcomes:

- Plan and apply various clinical study designs
- Recognize a research objective that would meet through a clinical trial
- Discuss the relative contributions of clinical judgment and clinical trials in evaluating new medical therapies.

- Apply various characteristics of statistical reasoning to a research objective in a clinical trial setting.

Course Contents:
Introduction to clinical trials, types and aspects of clinical trials; definition, phases and protocol: Design of Clinical Studies; Randomized controlled design, crossover design, cluster randomization, equivalence trial, large sample trial: Randomization; fixed randomization, adaptive randomization: Review of Methods of analysis; Randomization tests, stratified analysis, survival analysis: Surrogate endpoints; surrogate versus clinical endpoints, validation of surrogate end points: Statistical planning; sample size determination: Equivalency testing; Testing for the similarity of treatments: Multiple Testing; Multiple comparisons, subgroup analysis, multiple endpoints, covariate adjustment: Statistical Monitoring; methods of repeated testing of hypotheses over time: Noncompliance / Departure from intended treatment; Intent to treat principle, Efficacy analysis.

Recommended Books:

1. C. Jennison and B. W. Turnbull (1999). Group Sequential Methods with Applications to Clinical Trails, CRC Press.
2. Chow S.C. and Liu J.P. (2003): Design and Analysis of Clinical Trials: Concepts and Methodologies, 2nd Edition, Wiley.
3. E. Marubeni and M. G. Valsecchi (1994). Analyzing Survival Data from Clinical Trials and Observational Studies, Wiley and Sons.
4. Friedman L.M., Furberg C. and DeMets D.L. (2010). Fundamentals of Clinical Trials. Springer Verlag, New York.
5. Rosenberg, W.F., Lachin, J.M. (2002) Randomization in Clinical Trials: Theory and Practice. Wiley, New York.
6. J. L. Fleiss (1989). The Design and Analysis of Clinical Experiments. Wiley and Sons.
7. S. Piantadosi (1997). Clinical Trials: A Methodological Perspective. Wiley and Sons

STAT-820 Longitudinal Data Analysis (3Cr.Hours)

Course Objectives:
- To enhance the student's understanding and informed usage of modern methods in the analysis of longitudinal (repeated measures) data.
- To provide a foundation for research in statistical methods for longitudinal data.
- To understand statistical methods/models, particularly linear/generalized linear mixed models and GEE approaches, for analyzing longitudinal data

Learning Outcomes:
- Understand the advantages of using longitudinal data for research and decision-making.
- Manage longitudinal datasets and prepare these for statistical analysis.
- Understand and apply different approaches that can be used to model multivariate relationships with longitudinal data (e.g. fixed and random effects regression models).
- Analyze and interpret the results of longitudinal data analyses.

Course Contents:

Introduction: Definition, features, and objectives of longitudinal studies. Univariate Methods: Time by time analysis, Derived variable analysis, Repeated measures ANOVA. Classical Multivariate models for Longitudinal studies: Multivariate Analysis of Variance (MANOVA), Multivariate Growth Curve Models (MGC). General Linear Model: Weighted Least Squares (WLS) estimation, Restricted maximum likelihood estimation (REML), Robust estimation of standard errors. Serial Correlation: Stationary Models, Antedependence models. Generalized Linear models for Continuous and Discrete data: Marginal models, Random effects models, transition models. Missing values in longitudinal data: Types of missingness, Methods allowing for missingness/dropout. Time dependent covariates: Objectives, Causal models (e.g Marginal Structural models). Design Issues/Sample Size.

Recommended Books:

1. Liu, X. (2015). Methods and Applications of Longitudinal Data Analysis. Academic Press.
2. Fitzmaurice, G.M., Laird, N.M. and Ware, J.H. (2011). Applied Longitudinal Analysis. 2nd Edition. John Wiley & Sons, Hoboken, NJ.
3. Fitzmaurice, G.M., Davidian, M., Verbeke, G. and Molenberghs, G. (2008). Longitudinal Data Analysis. CRC press.
4. Newsom, J.D., Jones, R.N. and Hofer, S.M. (2012). Longitudinal Data Analysis: A practical guide for researchers in Aging, Health and Social Sciences. Routledge.
5. Diggle, P.J., Heagerty, P., Liang, K.Y. and Zeger, S.L. (2013). Analysis of Longitudinal Data, 2nd Edition. Oxford University Press, New York.
6. Verbeke, G. and Molenberghs, G. (2000). Linear Mixed Models for Longitudinal Data. Springer-Verlag, New York.

STAT-821 Causal Inference (3Cr.Hrs.)

Course Objectives:

- To enhance the student's understanding of the concepts used in causal inference
- To learn the appropriate use of modern tools for causal inference
- To provide a foundation for research in statistical methods for causal inference
- To place causal inference in the general picture of statistical learning theory

Learning Outcomes:

- Recognize a situation, where causal inference is required
- Apply the causal criteria to the assessment of the exposure outcome association
- Understand the appropriate usage of various statistical methods in causal inference analysis
- Discover the limitations inherent in using causal criteria for causal inference

Course Contents:

Introduction: Scientific criteria for causation, limitations of statistical methods; potential outcomes framework. Potential outcomes: Properties, causal effects measures, role of randomization. Confounding: Definition, role of randomization, observational studies, adjustment for confounders, inversely proportional to treatment weighting, Simpson's paradox, and attributable risk. Graphical models: Features, d-seperation, back door criteria, structural equations, effect of intervention. Propensity scores: Goals, techniques and their limitations. Longitudinal causal inference: Time dependent confounding, G-computational algorithm, selection bias, marginal structural models, nonignorable missing data. Mediation Analysis:

Direct, indirect effects, mediation measures, principle stratification. Instrumental variables: Noncompliance in clinical trials, Structural mean model, G-estimation. Structural Equations models: Inference, latent variables, generalized models. Sufficient competent cause model.

Recommended Books:

1. Hernan, M. and Robins, J. (2017) Causal Inference. Chapman-Hall/CRC.
2. Imbens, G.W. and Rubin, D.B. (2015). Causal Inference: for Statistics, Social, and Biomedical Sciences, An Introduction. Cambridge University Press.
3. Pearl, J (2009) Causality: models, reasoning, and inference. 2nd Edition. Cambridge University Press (Cambridge, UK).
4. Peter, J., Janzing, D. and Schölkopf, B. (2017). Elements of Causal Inference: Foundations and Learning Algorithms. MIT Press.
5. Rohlfing, I. (2012). Case Studies and Causal Inference: An integrative Framework. Palgrave Macmillan.
6. Rosenbaum P.R. (1995). Observational Studies. Springer-Verlag. New York, NY.

STAT-822 Performance Modeling (3Cr.Hrs.)

Stochastic Processes: Random Walks, Marko Chains, Markov Processes, Reversibility, Renewal Theory.
Queues: Simple Markovian Queues, the M/G/1 Queues, the G/G/1 Queue.
Single Class Queueing Networks: Introduction, Open Queueing Networks, Mean Value Analysis, Performance Measure for the State-Dependent Case, The Flow Equivalent Server Method.
Multi-Class Queueing Networks: Service Time Distributions, Types of Service Centre, Multi-Class Traffic Model, BCMP Theorem, Computational Algorithms for BCMP networks, Priority Disciplines, Quasi-Reversibility.
Approximate Methods: Decomposition, Fixed Point Method, Diffusion Approximation, Maximum Entropy Methods.
Time Delays: Time Delays in the Single Server Queue, Time Delays in Networks of Queues, Inversion of the Laplace Transforms, Approximate Methods.
Blocking in Queueing Networks: Introduction, Type of Blocking, Two Finite Queues in A Closed Network, Aggregation Markovian States, BAS Blocking, BBS Blocking, Representative Service Blocking.
Switching Network Models: Telephone Networks, Interconnection Networks For Parallel Processing Systems, Models of The Full Crossbar Switch, Multi-Stage Interconnection Networks, Models Of Synchronous MINIS, Models of Asynchronous MINIS, Interconnection Networks in a Queuing Model.

Recommended Books

1. Cox, D.R. and Miller, H.D. (1965). *"The Theory of Stochastic Processes*", Chapman and Hall, London.
2. Peter, G. Harrison and Naresn M.Patel (1993). *"Performance Modeling of Communication Networks and Computer Architectures"*, Prentice Hall London.
3. Takacs, L. (1962). "*Introduction to the Theory of Queues*", Oxford University Press.

STAT-823 Statistical Signal Processing (3Cr.Hrs.)

Introduction: detection theory in signal processing. The detection problem the mathematical detection problem, Hierarchy of detection problems, Role of asymptotic, Gaussian distribution, Chi-squared (non-central) distribution, F (non central) distribution, Tayleigh and Rician distribution, Quadratic form of Gaussian random variables, Monte Carlo performance evaluation, Normal Probability paper. Statistical Decision Theory: Neyman-Pearson Theorem, Minimum probability of error, Minimum Bayes Risk detector, composite hypothesis testing, Performance of GLRT for large data records, equivalent large data records tests, Asymptotically equivalent tests-no nuisance parameters.Determination Signals: Matched filters, Generalized matched filters, multiply signals, Linear model. Signal modeling and detection performance, Unknown amplitude, Sinusoidal detection, Classical linear model. Random Signals: Incompletely known signal covariance, Large data record approximations, Weak signal detection, Derivation of PDF for periodic Gaussian random process Estimator- correlator, Estimator-correlator fro large data records, general Gaussian detection, Detection performance of the estimator-correlator.
Unknown Noise Parameters: White Gaussian noise, Colored WSS Gaussian noise. Non Gaussian noise characteristics, deterministic signals with unknown parameters. Detection: Detection approaches, choosing detector. Description of problem, Extensions to the basic problem, Multiple change times, Signals processing examples. Complex/vector Extensions and Arrays Processing: Known PDFs. Uncorrelated from spatial sample to sample, Detectors for vector observations, Known deterministic signal is CWGN, Known deterministic signal and General noise covariance, Random signal in CWGN.

Recommended Books

1. Loren, D.Lutes, S.Shahron (1997). *"Stochastic Analysis of Structural and Mechanical Vitrating*", Prentice Hall.
2. Oppenheim Schafer (1993). "*Discrete Time Signal Processing*", Prentice Hall PTR New Jersey.
3. Stevan M.K. (1998). *"Fundamental of Statistical Signal Processing Volume-II Detection Theory".*
4. Therrien (1992). *"Discrete Random Signals and Statistical Signal Processing".*

STAT-824 Advanced Categorical Data Analysis (3Cr.Hrs.)

Course Objectives:

- To understand the basic concepts of categorical data analysis
- To recognize different types of categorical data and use appropriate methodology for categorical data
- To conduct statistical analysis using existing software and properly interpret the computer output.

Learning Outcomes:

- Implement basic categorical methods and combine them for the sampling estimation
- Obtain estimators, evaluate standard errors, construct confidence intervals and making statistical inference according to the categorical analysis techniques
- Demonstrate the knowledge to characterize, analyze and solve a wide range of problems related to the categorical data

Course Contents:

Introduction to categorical data analysis, Principles of likelihood-based inference, Probability distributions for contingency tables, Testing independence and inference for contingency tables. Simpson's paradox. Introduction to generalized linear models, Logistic regression, Model building, Alternative link functions for binary outcome, Diagnostics Receiver Operating Characteristic (ROC) Curve Analysis, Hyper-volume Under Manifold (HUM) Analysis., Exact methods and conditional logistic regression, Building and applying logistic regression models, Logit models for multinomial responses. Methods for analyzing matched case-control data. Count regression models. Quasi-likelihood and Generalized Estimating Equations.

Recommended Books:

1. Agresti, A. (2012). *Categorical Data Analysis.* 3rd edition. John Wiley & Sons.
2. Powers D. A. and Yu Xie (2008). *Statistical Methods for Categorical data analysis.* 2nd edition. Emerald Group publishing.
3. Agresti, A. (2007). *An Introduction to Categorical Data Analysis.* 2nd edition. John Wiley & Sons.
4. Hosmer, D. W. and Lemeshow S. (2004). *Applied Logistic Regression*. John Wiley & Sons.
5. Simonoff, J. S. (2003). *Analyzing Categorical Data.* Springer
6. Anderson, E. B. (1994). *The Statistical Analysis of Categorical Data.* Springer – Verlag.

STAT-826 Multilevel Modeling (3Cr.Hours)

Course Objectives:

- Introducing theory and practice of multilevel models.
- Learning to develop, implement, interpret and report research involving multilevel analysis.

Learning Outcomes:

- Principles and assumptions underlying multilevel.
- Estimate, confirm the validity of, and interpret such models using the statistical software.
- Apply multilevel models to a research problem according to a well-articulated research strategy.

Course Contents:

Introduction to multilevel models: Short review of regression, multilevel data structure, multilevel models, terminology and subscripts. Two Levels Models: Random intercept, random intercept and random slope (univariate and multivariate), Level-1 and level-2 residuals and assumption checking, Group level coefficients, logistic models (binary, multinomial and ordinal). Three and higher levels multilevel models.

Recommended Books:

1. Gelman, A., & Hill, J. (2007). Data Analysis Using Regression and Multilevel/Hierarchical Models. Cambridge University Press, Cambridge, UK, 2007. ISBN 978-0-521-68689-1.
2. Goldstein, H. (1995). Multilevel Statistical Models. London, Edward Arnold. New York, Halsted Press.
3. Jones, K., & Subramanian, S. V. (2015). Multilevel statistical models: concepts and applications. Boston, MA: Harvard T.H. Chan School of Public Health.
4. Kreft, I. G. G. & de Leeuw, J. (1998). Introducing multilevel modeling. Thousand Oaks: Sage Publications.
5. Longford, N. T. (1993). Random Coefficient Models. Oxford, Clarendon Press.
6. Raudenbush, S. W., & Bryk, A. S. (2002). Hierarchical Linear Models: Applications and Data Analysis Methods (2nd ed.). Thousand Oak, CA: SAGE Publications.
7. Snijders, T. A. B., & Bosker, R. J. (2012). Multilevel Analysis: An Introduction to Basic and Advanced Multilevel Modeling (2 ed.). London: Sage Publishers.

STAT-827 Structural Equation Models (3Cr.Hours)

Course Objectives:

- To develop a solid conceptual and theoretical understanding and ability to use SEM and its extensions correctly and effectively in research.
- Obtain thorough knowledge of structural equation modelling (SEM) and its special cases path analysis and factor analysis.
- Understanding of the statistical theory on which SEM is based. In addition to the common applications of SEM to cross-sectional, continuous, multivariate normally distributed data.
- How to apply SEM to multi-group data, longitudinal data, non-normal data, and (other) discrete data.

Learning Outcomes:

- Understanding of the statistical theory on which SEM is based.
- Students learn when and how to apply SEM and how to interpret SEM results, but they also learn the pitfalls of SEM, and to question the application and results of SEM.
- Students learn to read, understand, and interpret scientific articles in which SEM is applied.

Course Contents:

Structural Equation Models-Basics: Introduction, causation, types of variables, Myths about SEM. Specification of Observed Variable (Path) Models: Steps of SEM, Model Diagram Symbols, Causal Inference, Specification Concepts, Path Analysis Models, Recursive and Nonrecursive Models, Path Models for Longitudinal Data. Identification of Observed Variable (Path) Models: General Requirements, Unique Estimates, Rule for Recursive Models, Identification of Nonrecursive Models, Models with Feedback Loops and All Possible Disturbance Correlations, Graphical Rules for Other Types of Nonrecursive Models, Respecification of Nonrecursive Models that are Not Identified, A Healthy Perspective on Identification, Empirical Underidentification, Managing Identification Problems. Estimation and Local Fit Testing: Types of Estimators, Causal Effects in Path Analysis, Single-Equation

Methods, Simultaneous Methods, Maximum Likelihood Estimation, Fitting Models to Correlation Matrices, Alternative Estimators. Goodness of Fit Indices. How to improve fit. Mediation and Moderation Analysis via SEM. SEM for Categorical Variables. Power Analysis in SEM. Introduction of Software (AMOS, STATA, LISREL, Mplus, R, EQS etc) used for SEM.

Recommended Books

1. Beaujean, A.A. (2014). Latent variable modeling using R: A step-by-step guide. New York: Routledge.
2. Bollen, K. A. (1989). Structural Equations with Latent Variables. Wiley-Interscience.
3. Brown, T.A. (2006). Confirmatory factor analysis for applied research. New York: Guilford Press.
4. Byrne, B. M. (2006). Structural equation modeling with EQS and EQS/Windows: Basic concepts, applications, and programming. Thousand Oaks, CA: Sage Publications.
5. Byrne, B. M. (2016). Structural equation modeling with AMOS: Basic concepts, applications, and programming. Routledge - Taylor and Francis Group, New York.
6. Finkel, S. E. (1995). Causal Analysis with Panel Data. SAGE.
7. Hoyle, R.H. (2012). Handbook of Structural Equation Modeling. The Guilford Press, ISBN 978-1-60623-077-0.
8. Kline, R.B. (2015). Principles and Practice of Structural Equation Modeling, 4th ed. New York: The Guilford Press.
9. Schumacker, R.E., & Lomax, R.G. (2010). A beginner's guide to structural equation modeling. (3nd edition) N.J. Mahwah: Lawrence Erlbaum Associates.

STAT-828 Bayesian Statistical Techniques (3Cr.Hrs.)

Course Objectives:

- To impart a conceptual and advanced knowledge of Bayesian theory.
- To teach the development of models by using different priors and the estimation of the Bayes estimates.
- To develop the computational skills by using different algorithms to estimate the posterior distributions.
- To enable the students to draw inferences.

Learning Outcomes:

- Understanding basic techniques of Bayesian statistics for decision making.
- Using different simulation techniques to handle complex posterior distribution.
- Knowing the application of Bayesian statistics in different models.

Course Contents:

Philosophical differences between Classical and Bayesian statistics. Likelihood principles. Introduction to Prior information, Posterior distribution, kernel density, risk and loss functions. Posterior distribution for proportion. Construction and summarization of posterior distributions for the parameters involved in different continuous distributions specifically Normal and Pareto distributions. Prior predictive and posterior predictive distributions. Credible and prediction intervals. Bayesian testing of hypothesis. Bayes factor. Bayesian computations- specifically Markov Chain Monte Carlo Simulations (MCMC) and Metropolitan Hasting algorithm. Bayesian analysis of classical regression. Regression with unequal variances and correlations.

Evaluating and comparing models. Bayesian analysis of GLMs. Bayesian analysis of sample surveys, and designed experiments. Bayesian inference in the presence of missing data. Introduction to Dirichlet process and its Bayesian analysis.

Recommended Books

1. Berger, J. O. (2013). *Statistical decision theory and Bayesian analysis*. Springer Science & Business Media.
2. Gelman, A., Carlin, J. B., Stern, H. S., Dunson, D. B., Vehtari, A., & Rubin, D. B. (2014). *Bayesian data analysis* (Vol. 2). Boca Raton, FL: CRC press.
3. Bolstad, W. M., & Curran, J. M. (2016). *Introduction to Bayesian statistics*. John Wiley & Sons.
4. Albert, J. (2009). *Bayesian computation with R*. Springer Science & Business Media.

STAT-829 Fuzzy Analysis (3Cr.Hrs.)

Difference between fuzziness and variability, Indicator function and membership function, One dimensional fuzzy number, Fuzzy vectors and vectors of fuzzy numbers, Fuzzy numbers and characterizing functions, triangular norms, operations of fuzzy sets, Functions of fuzzy variables, Basic mathematical operations of fuzzy numbers, Histogram for fuzzy data, Descriptive statistics for fuzzy data, Combination of fuzzy sample, Classical statistical inference for fuzzy data.

Recommended Books

1. Buckley, J. J. (2013). *Fuzzy Statistics*. Springer, Heidelberg
2. Nguyen, G. T. and Wu, B. (2010). *Fundamentals of Statistics with Fuzzy Data*. Springer, New York.
3. Viertl, R. (2011). *Statistical Methods for Fuzzy Data*. Wiley, Chichester.

STAT-830 Data Mining (3Cr.Hrs.)

Overview of data mining, Data visualization and pre-processing, Data mining in practice Models and patterns, Introduction to data mining using SPSS and other software, Classification trees, Predictive modelling, Descriptive modelling, Classification models, Clustering.

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Recommended Books

1. Han, J., Kamber, M. and Pei, J (2012) Data Mining: Concepts and Techniques. Morgan Kaufmann.
2. Hand, D., Mannila, H. and Smyth, P. (2001) Principles of Data Mining. MIT Press: Massachusets.
3. Witten, I. H. and Frank, E. (2005) Data Mining: Practical machine learning tools and techniques (2nd ed.) Margan Kaufmann: USA.
4. Duda, R. O., Hart, P. E. and Stork, D. G. (2001) Pattern Classification (2nd ed.) Wiley-Interscience: USA.

STAT-831 Randomized Response (3Cr.Hrs.)

Introduction to Randomized Response: Warner Model, the unrelated-question model, polychotomous population and multiattribute situations, Techniques for quantitative characteristics, Efficient estimation and protection of privacy, Miscellaneous topics on randomize response techniques: a Bayesian approach, lying models, direct response and some allied methods for sensitive characters, Randomized Response in a finite population setting: sampling with unequal probabilities.

Recommended Books

1. Chaudhuri, A. (2011). Randomized Response and Indirect Questioning Techniques in Surveys, Chapman & Hall.
2. Chaudhuri, A. and Mukherjee, R. (1987). Randomized Response: Theory and Techniques, Marcel Dekker.
3. Fox, J. A. and Tracy, P.E. (1986). Randomized Response: A Method for Sensitive Surveys, Sage Publications.
4. Paul, M. (1981). Randomized Response Technique: getting in touch with touchy questions, COMAP Publisher.
5. Wayne W. D. (1993). Collecting Sensitive Data by Randomized Response: an annotated bibliography, Georgia State University Business Press.

STAT-832 Statistical Learning and Data Analytics (3Cr.Hrs.)

Types of learning problems, high-dimensional phenomena, computational challenges
Decision theory, surrogate losses, empirical risk minimization, Nonlinear & convex optimization, linear regression, bias/variance trade-off, Regularization, ridge and lasso regression, localized methods, Linear methods for classification: LDA, logistic regression, SVM, Model selection, cross-validation, feature selection and engineering, Reproducing kernels and spaces, kernel-based learning methods, Tree-based methods, random forests, boosting, PCA, random projections, kernel PCA, ICA, Matrix factorization, topic models, EM Algorithm, mixture models, *k*-means, Graph Laplacian, spectral clustering, embeddings, Neural networks and deep learning.

Recommended Books

1. Hastie, T., Tibshirani, R., and Friedman, J. (2009). *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*. 2nd Edition. Springer.
2. Mohri, M., Rostamizadeh, A. and Talwalkar, A. (2012). *Foundations of Machine Learning*. MIT Press, Cambridge, Massachusetts.
3. K. Murphy, K.P. (2012). *Machine Learning: A Probabilistic Perspective*. MIT Press, Cambridge, Massachusetts.
4. Shalev-Schwartz, S. and Ben-David, S. (2014). *Understanding Machine Learning*. Cambridge University Press.
5. Clarke, B., Fokoué, E. and Zhang, H.H. (2009) *Principles and Theory for Data Mining and Machine Learning*. Springer, New York.
6. Duda, R.O., Hart, P.E., and Stork, D.G. (2001). *Pattern Classification*. 2nd Edition Wiley-Interscience.

7. Goodfellow, I., Bengio, Y. and Courville, A. (2016) *Deep Learning*. MIT Press Cambridge, Massachusetts

STAT-833 Financial Econometrics (3Cr.Hrs.)

Simple Returns, Log (Continuous) Returns, Comparison of functions log(1+x) and x, Adjustment for Dividends, Constant Expected Returns (CER) Model, Characteristics of Financial Returns, Skewness, Kurtosis, Bera-Jarque test for normality, Autocorrelation, Ljung-Box Q statistic test of independence, Geometric Random Walk, Clustered Volatility, Portfolio Mean Return, Variance of Portfolio Return, Estimation of Portfolio Mean, Variance, and Standard Deviation, Minimum Variance Portfolio, Efficient Frontier, Tangency Portfolio, Capital Market Line (CML), Quadratic Utility, Optimal Portfolio Choice, Fragility of Optimal Portfolio Weights. CAPM, Security Market Line (SML), Security Characteristic Line (SCL), Portfolio and Security Performance Measures, Jensen's alpha, Appraisal Ratio, Information Ratio, Sharpe's Ratio, Treynor's Ratio, Factor Models of Returns, Fama-French 3-Factor Model, Carhart Model, Other Factor Models, Fragility of Coefficients of Return Model. Typical Event Study Time Line, Market Model with Pulse Dummies, Joint Test of Significance of Pulse Dummies, An Application. Definition, Weak Form, Semi-Strong Form, Strong Form, Evidence For, Evidence Against – Behavioral Economics, The Over-reaction Hypothesis, The Momentum Effect – Carhart model F. Smart Beta Portfolios. Definition of Term Structure, Deriving Forward Rates from the Term Structure, The Expectations Hypothesis of the Term Structure of Interest Rates, Testing the Expectations Hypothesis Definition of Co-integration, Engle-Granger Residual – based tests of Co-integration, The Error Correction Model, Applications, Expectations Hypothesis of the Term Structure, Spot and Futures prices, Paired Investments.

ARCH and GARCH models, Forecasting Volatility, Multivariate GARCH models, Applications, Black-Scholes Model, Simulating the Price of a Financial Option, Risk Metrics, Value at Risk computations Conditional Betas and Dynamic Hedge Ratios. Optimal Hedge Ratio, Logit Models of Financial Distress of Firms, Mergers and Acquisitions, Pecking Order, Hypothesis, Ordered Probit Analysis of Bond Ratings

Recommended Books

1. Brooks, C. (2014). *Introductory Econometrics for Finance*, 3rd Edition, Cambridge University Press.
2. Campbell, J.Y., Lo,A.W. and A. C. MacKinlay, A.C. (1997).*The Econometrics of Financial Market.* Princeton University Press.
3. Hamilton, J.D. (1994). *Time Series Analysis.* Princeton University Press
4. Mills, T.C. (1999). *The Econometric Modelling of Financial Time Seri.* Cambridge University Press, 2nd edition.
5. Taylor, S. J. (2005). *Asset Price Dynamics, Volatility, and Prediction*, Princeton University Press.
6. Tsay, R.S. (2005). *Analysis of Financial Time Series,* Wiley Series in Probability and Statistics.

STAT-834 Advanced Demographics Techniques (3Cr.Hrs.)

Review of Basic Demographic Concepts, Demographic Rates and Ratios, Population Growth Rates, Age-Specific Rates and Probabilities, Standardization, Decomposition, The Life Table, Single Decrement Processes, Variance Estimation, Multiple Decrement Processes.
Fertility Measures, Demographic Translation, The Stable Population Model, Age Distributions and Population Momentum, Age Patterns of Vital Events, Increment-Decrement Life Tables, Cohort Component Projection, Multiregional Projection, Data Quality, Indirect Estimation, Projecting Completed Fertility

Recommended Books

1. Preston, S., P. Heuveline, and M. Guillot. (2001). *Demography: Measuring and Modeling Population Processes*. London: Blackwell Publishers
2. Rowland, D.T. (2003). *Demographic Methods and Concepts*. Oxford University Press.
3. Keyfitz, N. and Caswell, H. (2005). Applied Mathematical Demography. Third Edition. Springer.
4. Siegel, J.S. and Swanson, D.A., editors (2004). The Methods and Materials of Demography, 2nd Edition, Elsevier Academic Press.
5. Watcher, K.W. (2014). Essential Demographic Methods. Harvard University Press.
6. Moultrie, T.A., Hill, A. G., Hill, K., Timaeus, I. M. and Zaba, B. (2013). Tools for Demographic Estimation. Paris: International Union for the Scientific Study of Population.

STAT-835 Advanced Multivariate Analysis (3Cr.Hrs.)

Course Objectives:

- To impart the conceptual and advanced knowledge of multivariate data.
- To teach various advanced techniques to handle the challenges presented by these data.
- To develop sound knowledge of multivariate theories and its application in different fields.

Learning Outcomes:

- Understanding of the link between multivariate techniques and corresponding univariate techniques.
- Recognition of the variety of advanced multivariate techniques and their proficient applications.
- Development of the skill to summarize, analyze and interpret the multivariate data.

Course Contents:

Review of multivariate methods, distance, quadratic form, Eigen analysis, spectral decomposition, singular-value decomposition. Descriptive statistics for multivariate data, multivariate normal distribution and derivation of its properties, principal component analysis, correspondence analysis, factor analysis, canonical correlation analysis, discriminant analysis, cluster analysis, multidimensional scaling, classification and regression tree (CART), Path analysis. Multivariate linear model: multivariate regression, multivariate analysis of variance (MANOVA) and multivariate analysis of covariance (MANCOVA).

Recommended Books:

1. Anderson, T.W. (2003). *An Introduction to Multivariate Statistical Analysis*, John Wiley & Sons, New York, USA.
2. Johnson, R. A. and Wichern, D. W. (2007). *Applied Multivariate Statistical Analysis*, Prentice Hall, New York, USA.
3. Manly, B.F.J. (2004). *Multivariate Statistical Methods: A Primer*, Chapman and Hall/CRC, New York, USA.
4. Mardia, K. V., Kent, J. T. and Bibby, J. M. (1976). *Multivariate Analysis*, Academic Press, New York, USA.
5. Rencher, A.C. and Christensen, W.F. (2012). *Methods of Multivariate Analysis*, John Wiley & Sons, New York, USA.

STAT-836 Exploratory Data Analysis and Visualization (3Cr.Hrs.)

Learning Objectives:

- to provide solid understanding of the process of Exploratory Data Analysis
- to educate students in data exploration, analysis, and visualization
- to train students in industry standard tools for data analysis and visualization

Learning outcomes:

- describe exploratory data analysis and visualization concepts
- describe data analysis and visualization models and algorithms
- describe applicability of different data analysis and visualization models techniques to solve real-world problems
- acquire and pre-process data
- apply exploratory data analysis to some real data sets and provide interpretations via relevant visualization

Course Contents:

What is EDA? Data sources, Data types, Data structures, Merging datasets, Samples and sampling bias, Data dictionaries and meta-data. Start Exploring: Using software: from spreadsheets and beyond (Excel/Tableau/R/STATA/SPSS etc), Getting an overview: filtering, sorting, summary statistics, and more. Detecting and dealing with exceptions: missing values, outliers and extreme values. Transforming variables and creating new derived variables. Creating Data Stories: Organizing information, Annotation, Sharing, Beyond visualization: dimension reduction in a nutshell (clustering and PCA). Evaluating Your Discoveries and Data Stories :Is the "aha!" really an "aha?", Who should care, why they should care, Implications of discoveries and data stories

Recommended Books

1. Peng R. (2015) Exploratory Data Analysis with R http://leanpub.com/exdata
2. Chang, W. (2013). R Graphics Cookbook. O'Reilly. http://www.cookbook-r.com/
3. Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis (2nd) Springer. http://ggplot2.org/book/; http://hadley.nz/

STAT-837 Repeated Measure Analysis (3Cr.Hours)

Introduction of repeated measure designs, models and assumptions, variance–covariance structure, box's correction, Huynh-Feldt (HF) condition, circularity assumption, necessary and sufficient conditions for circularity, mauchley sphere city test, trend analysis, test oftrend analysis, models with interaction, measures of association and power in univariate repeated measure design, application of repeated measure in basic design and analysis of co-variance, multi factor experiments in repeated measure designs, two factors experiment with one factor repeated measure, three factor experiments with repeated measure, controlling sequence effect, unequal group size, measures of association and statistical power in multifactor repeated measure designs.

Recommended Books

1. Crowder M. J. and Hand D. J. (1999). Analysis of Repeated Measures, Chapman and Hall.
2. Montgomery, D.C. (2001). "Design and Analysis of Experiment", John Wiley and Sons. New York.
3. Peng R. (2015) Exploratory Data Analysis with R http://leanpub.com/exdata
4. Stevens, J. (1996). "Applied multivariate statistics for the socialsciences", 3rd ed. Lawrence Erlbaum Associates, New Jersey, P:450-518
5. Weinfurt, K.P. (1995). "Repeated Measure Analysis", In L.G. Grimm

STAT-838 Mixture Distributions (3Cr.Hrs.)

Statistical Applications, Mathematical aspects: identifiability, multimodality, negative mixing weights, general properties. Estimating mixing parameters: graphical methods, method of moments, maximum likelihood, Bayesian, minimum distance of distribution functions, minimum distance of transforms and numerical decomposition of mixtures.

Recommended Books

1. Dias, J. G. (2004). Finite mixture models. *Review, Applications, and Computer-intensive Methods (PhD Thesis). Ridderprint, The Netherlands*.
2. Demidenko, E. (2013). *Mixed models: theory and applications with R*. John Wiley & Sons.
3. Titterington, D. M., Smith, A. F., & Makov, U. E. (1985). *Statistical analysis of finite mixture distributions*. Wiley.
4. Everitt, B. S. (2004). Mixture Distributions—I. *Encyclopedia of statistical sciences*, *7*.

STAT-839 Ecological Statistics (3Cr.Hrs.)

Course Objectives:

- Introduce the Ecological data in specific reference to a statistical frame work.
- To comprehend the common form of ecological data and discuss their associated models.

- Model fitting approaches including the incorporation of heterogeneity with in the given biological system and the integration of different data sources.

Learning Outcomes:

- Focus on learning ecological intensive statistics from an applied perspective.
- Evaluate the structure of ecological data, resulting from observational and experimental studies.
- Analysis of ecological data using appropriate statistical techniques.

Course Contents:

Introduction to Ecological data, Diversity in ecological data, spatial patterns in community ecological data, Spatial Eigen function analysis: simple ordination Principal component analysis (PCA), Component Analysis (CA), Principal Component Ordination Analysis (PCOA), multivariate regression analysis and Canonical Analysis, permutation test. Introduction to beta diversity in environmental sorting and to community based processes including neural processes. The cycle of ecological research and the role of Statistical Modeling: framing ecological questions, ecological hypothesis, empirical models, study design, statistical models, Ecological Data Collection, Statistical Modelling, Answer Question else New Question.

Recommended Books:

1. Ludwig, J. A., & Reynolds, J. F. (1988). Statistical ecology: a primer in methods and computing (Vol. 1). John Wiley & Sons.
2. Fox, G. A., Negrete-Yankelevich, S., & Sosa, V. J. (Eds.). (2015). Ecological statistics: contemporary theory and application. Oxford University Press, USA.
3. Smith, E. P. (2002). Ecological statistics. Encyclopedia of environmetrics.
4. Wiegand, T., & Moloney, K. A. (2013). Handbook of spatial point-pattern analysis in ecology. Chapman and Hall/CRC.
5. Grieg-Smith, P. (1964). "*Quantitative Plant Ecology*", Butter Worth.
6. Pielou, E.C. (1975). *"Ecological Diversity*", Wiley, New York.

STAT-840 Classification and Random Forecast Techniques (3Cr.Hrs.)

Supervised Learning Algorithm, Unsupervised Learning Algorithm, Semi-Supervised Learning. Basic terminology/concepts like Tree-structured models, Decision Node, End Node, Root Node, Child Node, Splitting, Pruning, Overfitting, Training and testing data set etc.History and Definition, how to learn a decision tree (explanation by simple example), splitting criteria, defining decision rules, interpreting the results, commonly used decision trees, strength and weakness of a decision tree.Difference between classification and regression tree, selection of attributes, concept of impurity, different impurity measures: Gini's coefficient, Entropy etc. , stopping criterion, greedy algorithm of CART, problems associated with CART: Overfitting, Bias etc. Use of SPSS or R language to draw a CART.
Different Ensembles: BOOSTING, BAGGING, RANDOM FOREST, Randomness involves in Random Forest, Algorithm of Random Forest, Number of trees in Random Forest, Out-of-bag error in Random Forest, Use of R package for Random Forest

Recommended Books

1. Breiman, L. (1984). Classification and Regression Trees. New York: Routledge.
2. Zhang, C., & Ma, Y. (Eds.). (2012). Ensemble machine learning: methods and applications. Springer Science & Business Media.
3. Smith, C. & Koning, M. (2017). Decision Trees and Random Forests : A Visual Introduction For Beginners, Penguin Random House, South Africa.

STAT-841 Item Response Theory (3Cr.Hrs.)

Foundations of Item Response Theory: Historical Perspectives, and Basic Statistical Prerequisites. Basic IRT Concepts, Models, and Assumptions. Model Specifications and Scale Characteristics. Introduction to Mplus Software for IRT
Estimation of IRT Models: IRT Models for Polytomous Response Data. Estimation of Item Response Models, Assessment of Model Fit. Polytomous IRT Models
Reliability in IRT/Test Development/Computerized Adaptive Testing:
Latent Trait Reliability, Test Development with IRT, Computerized Adaptive Testing, Scale Development
Equating/Item and Test Bias/Differential Item Functioning
Advanced IRT Models and Topics: Multidimensional IRT, Diagnostic Classification Models, Comparing IRT with Other Models

Recommended Books

1. Baker, F. B., & Kim, S. H. (2004). Item response theory: Parameter estimation techniques. New York, NY: Marcel Dekker.
2. de Ayala, R. J. (2009). The theory and practice of item response theory. New York: Guildford.
3. Embretson, S. E., & Reise, S. P. (2000). Item response theory for psychologists. Psychology press.
4. Hambleton, R. K., & Swaminathan, H. (1985). Item response theory principles and applications. Boston, MA: Kluwer-Nijhoff Publishing.
5. Lord, F.M. (1980). Applications of Item Response Theory to Practical Testing Problems. Hillsdale, NJ: Lawrence Erlbaum.
6. McDonald, R. P. (1999). Test theory: A unified approach. Mahwah, NJ: Lawrence Erlbaum.
7. Thissen, D., & Wainer, H. (Eds.). (2001). Test Scoring . Mahwah, NJ: Lawrence Erlbaum.
8. van der Linden, W. J., & Hambleton, R. K. (Eds.). (1997). Handbook of modern item response theory. New York, NY: Springer.

STAT-842 Advanced Machine Learning (3Cr.Hrs.)

Supervised Learning, Discriminative Algorithms, Generative Algorithms, Learning Theory, Regularization and Model Selection, Principal Components Analysis, Unsupervised Learning, k-means clustering, Independent Components Analysis, Kernel Smoothing Methods: Introduction

to Various Kernels. Reinforcement Learning and Control, Advanced Topics in Random Forests. Introduction to Neural Networks. High-Dimensional Problems: p >> N.
Application of the above, where possible, in any of R, SAS, MATLAB or C++.

Recommended Books:

1. Gordon, A. (1999). Classification (2nd edition), Chapman and Hall/CRC Press, London.
2. James. G., Witten. D., Hastie. T., Tibshirani. R. (2013). An Introduction to Statistical Learning: with Applications in R. Springer-Verlag New York
3. T. Hastie, R. Tibshirani, and J. Friedman (2009). The Elements of Statistical Learning. Springer series in statistics. Springer, New York.
4. Marsland, M. (2009). Machine Learning: An Algorithmic Perspective, Chapman & Hall.
5. Zhi-Hua Zhou. (2012). Ensemble Methods: Foundations and Algorithms (1st ed.). Chapman & Hall/CRC.
6. Bishop, C. (2006). Pattern Recognition and Machine Learning, Springer, New York
7. Breiman, L., Friedman, J., Olshen, R. and Stone, C. (1984). Classification and Regression Trees, Wadsworth, New York.
8. Cherkassky, V. and Mulier, F. (2007). Learning from Data (2nd Edition), Wiley, New York.
9. Duda, R., Hart, P. and Stork, D. (2000). Pattern Classification (2nd Edition), Wiley, New York.
10. Efron, B. and Tibshirani, R. (1993). An Introduction to the Bootstrap, Chapman and Hall, London.

STAT-843 Bio-Informatics (3Cr.Hrs.)

Introduction to Bioinformatics, Molecular Data Types, Access to Bioinformatics Data, Pairwise Sequence Alignment, Basic local Alignment Search Tool (BLAST), Sequence alignment, Molecular Phylogeny and Evolution, Motif Finding and Applications, Multiple sequence alignment and Phylogeny, SNPs and GWAS analysis, R programming, Microarray Data Analysis and Statistics, Differential expression analysis statistics, Clustering and Classification, Clustering expression data, Protein-Protein Interaction Networks.

Recommended Books:

1. Agostino, Michael. Practical bioinformatics. Garland Science, 2012.
2. Brown, Stuart M." Next-Generation DNA Sequencing Informatics" Cold Spring Harbor Laboratory Press, 2013.
3. Chen, Yi-Ping Phoebe, ed. Bioinformatics technologies. Springer Science & Business Media, 2005.
4. Deonier, Richard C., Simon Tavaré, and Michael S. Waterman. Computational genome analysis: an introduction. Springer Science & Business Media, 2005.
5. Ghosh, Zhumur, and Bibekanand Mallick. Bioinformatics: Principles and Applications. Oxford University Press, 2008.
6. Gopal S. , Price R. , Tymann P. & Haake A. , Bioinformatics with Fundamentals of Genomics and Proteomics, Tata McGraw Hill Education Pvt. Ltd. , 2000.
7. Hurwitz, Judith, et al. Big data for dummies. John Wiley & Sons, 2013.
8. Lesk, Arthur. Introduction to genomics. Oxford University Press, 2017.
9. Orengo C, Jones D. T., & Thornton J. M., Bioinformatics: Genes, proteins and computers. Garland Science, 2012.

COURSE FOR NON-STATISTICS MAJOR
BS/ Masters and MS/M.Phil Programs
2019-onwards

List of courses

For BS and Masters Programs

Course Code	Course Title	Credit Hours	Pre-requisite
The Courses of to be Offered in BS 1st and 2nd Semester			
STAT-301	Fundamentals of Statistics	3	
STAT-302	Descriptive Statistics	3	
STAT-303	Business Statistics	3	
STAT-311	Inferential Statistics	3	
The Courses of to be Offered in BS 3rd and 4th Semester			
STAT-401	Biostatistics	3	
STAT-402	Probability and Statistics	3	
STAT-403	Probability Theory	3	
STAT-404	Applied Statistical Methods	3	
Masters Programs			
The First two Course to be Offered in M.A/M. Sc 1st, 2nd and the Second in 3rd , 4th Semester			
STAT-501	Elements of Statistics and Biometry	3	
STAT-502	Elements of Statistics	3	
STAT-602	Basics of Statistics	3	

For MS/M. Phil Program

Course Code	Course Title	Credit Hours
STAT-701	Statistics in Education	3
STAT-702	Statistical Analysis	3
STAT-703	Mathematical Statistics	3

Details of the Courses

STAT-301 Fundamentals of Statistics (3 Cr.Hrs)

Learning Objectives:
To give the basic knowledge of Statistics to the students not majoring in Statistics

Intended Learning Outcomes:

- After completion of this course the student should be able to:
- Understand the use of the essential tools of basic Statistics;
- Organize and display the data through tables and graphs.
- Understand and differentiate between the types of data and variables.
- Evaluate and Interpret basic descriptive statistics.
- Apply the concepts and the techniques in their respective disciplines.

Course Contents:
Introduction to Statistics: Definition, scope, Descriptive and inferential Statistics scope. Types of variables. Presentation of data: classification of data, tabulation, Graphs and Charts: Bar charts, Pie charts, histogram frequency polygon and curve and their interpretation.
Measures of Central Tendency; mean, median and mode; properties, usage, limitations and comparison through examples. Measure of dispersion; Variance and standard deviation; properties. Co-efficient of variation.
Simple linear regression, Measures of correlation.
Introduction to Sampling and sampling Distributions. Importance of sampling, Statistics vs. parameters b. sampling errors c. The probability and non-probability sampling.
Hypothesis Testing; The logic of hypothesis tests; translating a research question into null and alternative hypotheses ii. P-values; Type I and Type II errors. Testing of hypothesis about mean and difference of mean.

Books Recommended:

1. Chaudhry, S.M.and Kamal, S. (1996), "Introduction to Statistical Theory" Parts I & II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.
2. Chaudhry, S.M.and Kamal, S. (1996), "Introduction to Statistical Theory" Parts I & II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.
3. Clark, G.M and Cooke, D. (1998), "A Basic Course in Statistics" 4th ed, Arnold, London.
4. Mclave, J.T., Benson, P.G. and Snitch, T. (2005) "Statistics for Business & Economics" 9th ed.Prentice Hall, New Jersey.

5. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "Probability and Statistics", 2nd ed. Schaums Outlines Series. McGraw Hill. NY.
6. Walpole, R.E., Myers, R.H and Myers, S.L. (1998), "Probability and Statistics for Engineers and Scientist" 6th edition, Prentice Hall, NY.

STAT-302 Descriptive Statistics (3 Cr.Hrs)

Course Objectives:
The objective is to provide a basic understanding of data analysis using statistics and to use computational tools on problems of applied nature.

Outcomes:
After completion of this course the students will be able to:

- Demonstrate their understanding of descriptive statistics.
- Effectively visualize the data. Carry out practical application of data visualization.
- Carry out data analysis.

Course Contents:
Introduction to descriptive statistics, types of variables, measurement scales. Data collection principles. Examining and visualizing numerical and categorical data; Tabulation of data. Graphical methods, histograms, frequency polygon, frequency curve, ogive, bar plots, box plot. Measure of central tendency; average, median, mode. Measure of Dispersion, the variance, standard deviation, co-efficient of variation, moments, properties of variance and standard deviation.
Introduction to Sampling and sampling Distributions. Importance of sampling, Statistics vs. parameters, sampling and non-sampling errors, the probability and non-probability sampling. Correlation and regression; simple linear regression, properties and model fitting. Co-efficient of Determination, Correlation.

Books Recommended:

7. Clark, G.M. and Cooke, D. (1998), "A Basic Course in Statistics" 4th ed, Arnold, London.
8. Chaudhry. S.M. (2006), "Introduction to Statistical Theory" Parts I & II, Ilmi Kitab Khana, Lahore, Pakistan.
9. Mclave, J.T., Benson, P.G. and Snitch, T. (2005) "Statistics for Business & Economics" 9th ed.Prentice Hall, New Jersey.
10. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "Probability and Statistics", 2nd ed. Schaums Outlines Series. McGraw Hill. NY.
11. Walpole, R.E., Myers, R.H and Myers, S.L. (1998), "Probability and Statistics for Engineers and Scientist" 6th edition, Prentice Hall, NY.

STAT-311 Inferential Statistics (3 Cr.Hrs)

Course Objectives:
To provide understanding of basic techniques of estimation, their properties and applications.
To test, deduce and infer the validity of different types of hypotheses and models built on the basis of the raw data collected in diverse problem-situations.

Learning Outcomes:
After completion of this course the students shall:

- Have the knowledge of the sampling distributions and their properties.
- Derive the appropriate estimators for parameters.
- Use appropriate hypotheses testing procedures.

Course Contents:

Inferential Statistics; Sampling distribution; Estimation: Point Estimation. Properties of a Good Estimator. Interval Estimation; interval Estimation of population mean. Large and small sample confidence intervals for Population Mean. Hypothesis Testing; Formulation of null and alternative hypothesis, level of significance, Types of errors. Hypothesis Testing for Population Mean and difference of means using Z and T-statistics. Analysis of Variance; One way analysis of variance, two way analysis of variance. Testing of hypothesis; testing the significance of correlation co-efficient and regression co-efficient.

Pre-requisite: STAT-301

Books Recommended:

8. Clark, G.M. and Cooke, D. (1998). A Basic Course in Statistics. 4th ed, Arnold, London.
9. Casella, G. and Berger, R.L. (2008). Statistical Inference, Cengage Learning, New York, USA.
10. Ross, S. (2017). A first course in Probability. 9th edition. Pearson Education Limited.
11. Srivastava, M.K., Khan, A.H. and Srivastava, N. (2014). Statistical Inference: Theory of Estimation. Prentice-Hall of India Pvt. Ltd
12. Walpole, RE., Myers, R.H. and Myers, S.L. (1998), "Probability and Statistics for Engineers and Scientist" 6th edition, Prentice Hall, NY.

STAT-401 Biostatistics (3Cr.Hrs.)

Course Objectives:
To provide knowledge of importance of and its application in Biological Sciences.
Understanding of use of statistical techniques to summarize and analyze Biological data.

Learning Outcomes:
Upon successful completion of this course the students will be able to:

- Understand the applications of statistical tools in biological science.
- Demonstrate an understanding of the central concepts of statistical theory in Biological Sciences.

- Apply appropriate statistical techniques to Biological data and analyze and communicate the results of statistical analysis effectively.

Course Contents:
Introduction to Biostatistics, scope. Types of data, variables; Categorical, numerical and censored data. Descriptive Statistics; Measure of central tendency; mean, median, mode. Measure of dispersion; Variance and standard deviation. Simple linear regression; model fitting. Correlation; correlation co-efficient, co-efficient of determination. Logistic regression. Logit transformations and their analysis, p values and its importance and role. Hypothesis testing.

STAT-402 Probability and Statistics (3 Cr.Hrs)

Learning Objectives:
The course is designed to enable the students to understand basic concepts of Statistics, descriptive statistics and probability; conditional probability, random variables and probability distributions.

Learning Outcomes:
At the end of the course the students will be able to:

- Demonstrate basic descriptive statistics and analyse and interpret data.
- Demonstrate the basic knowledge of probability and probability distributions.
- Use basic counting techniques (multiplication rule, combinations, and permutations) to compute probability and odds.

Course Contents:
Introduction to Statistics: Descriptive Statistics, Graphical presentation of data, Histogram, Bar charts, Pie charts, box-plot, stem and leaf plot. Measures of Central Tendency; mean, median and mode. Measure of dispersion; Variance and standard deviation; properties. Co-efficient of variation. Correlation and regression. Hypothesis testing.
Introduction to counting techniques; Permutation, combination. Basic concept of probability, random experiment, event, sample space. Laws of probability, conditional probability, Bayes theorem with application to discrete and continuous random variable. Random variables and Probability Distributions; Discrete Random Variables, Bernoulli trials, Binomial and Poisson distributions. Continuous Random Variable, probability density function and its properties. Normal Distribution and its properties.

Books Recommended

1. Clark, G.M. and Cooke, D. (1998), "A Basic Course in Statistics" 4th ed, Arnold, London.
2. Chaudhry. S.M.and Kamal, S. (1996), "Introduction to Statistical Theory" Parts I & II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.
3. Mclave, J.T., Benson, P.G. and Snitch, T. (2005) "Statistics for Business & Economics" 9t ed, Prentice Hall, New Jersey.
4. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "Probability and Statistics", 2nd ed. Schaums Outlines Series. McGraw Hill. NY.
5. Walpole, RE., Myers, R.H and Myers, S.L. (1998), 'Probability and Statistics for Engineers and Scientist" 6th edition, Prentice Hall, NY.

6. Weiss, N.A. (1997), "Introductory Statistics" 4th ed. Addison-Wesley Pub. Company, Inc.

STAT-403 Probability Theory (3 Cr.Hrs)

Learning Objectives:
The course is designed to introduce the fundamentals of probability theory and its applications. To provide knowledge of basic laws of probability, random variables, random processes and probability distributions.

Learning Outcomes:
At the end of the course the students will be able to:

- Demonstrate the knowledge of probability and probability distributions.
- Apply basic counting techniques (multiplication rule, combinations, and permutations) to compute probability and odds.

Course Contents:
Introduction to Probability theory; counting techniques; Permutation, Combination. Random experiment, event, sample space (continuous and discrete). Laws of probability, conditional probability, independent events. Bayes theorem. Random variables; Mean and variance of a discrete random variable. P
Probability Distributions; Discrete Probability Distribution and its properties. Bernoulli trials, Binomial and Poisson distributions. Continuous Random Variable, probability density function and its properties. Uniform distribution, Normal Distribution and its properties.
Expectation; Moments, Expectation of a function of a random variable, characteristic function.

Books Recommended

1. Clark, G.M. and Cooke, D. (1998), "A Basic Course in Statistics" 4th ed, Arnold, London.
2. Chaudhry. S.M.and Kamal, S. (1996), "Introduction to Statistical Theory" Parts I & II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.
3. Mclave, J.T., Benson, P.G. and Snitch, T. (2005) "Statistics for Business & Economics" 9t ed, Prentice Hall, New Jersey.
4. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "Probability and Statistics", 2nd ed. Schaums Outlines Series. McGraw Hill. NY.
5. Walpole, RE., Myers, R.H and Myers, S.L. (1998), 'Probability and Statistics for Engineers and Scientist" 6th edition, Prentice Hall, NY.
6. Weiss, N.A. (1997), "Introductory Statistics" 4th ed. Addison-Wesley Pub. Company, Inc.

STAT-404 Applied Statistical Methods (3 Cr.Hrs)

Course Objective:
To provide knowledge of statistics and applications of statistical techniques to real world problems.

Learning Outcomes:
Upon successful completion of this course the students will be able to:

- Demonstrate the application of statistical methods.
- to use statistical software to analyze data and report and interpret the results of a statistical analysis;
- Highlight the limitations and possible sources of errors in the analysis.

Course Contents:
Fundamentals of statistics for data analysis in research. Data collection, exploratory data analysis, random variables, types of variables. Sampling: Need of sampling, Sample versus population, Random and nonrandom sampling, concepts of statistic and population parameter. Sampling techniques: Simple Random, Stratified and Systematic random sampling. Survey problem framing of questionnaire. Sampling and Non-Sampling Errors.
Review of estimation, confidence intervals, hypothesis testing. Linear regression and correlation, analysis of variance; one-way ANOVA, and data analysis. Data analysis using statistical software.

Books Recommended

7. Clark, G.M. and Cooke, D. (1998), "A Basic Course in Statistics" 4th ed, Arnold, London.
8. Mclave, J.T. Benson, P.G. and Snitch, T. (2005) "Statistics for Business & Economics" 9th Prentice Hall New Jersey.
9. Silverman, B. W. (2018). Density estimation for statistics and data analysis. Routledge.
10. Walpole, P.E. Myers, RH., Myers S.L. (1998), "Probability and Statistics for Engineers and Scientists", Prentice Hall.
11. Chaudhry, S.M. and S. Kamal, (1996), "introduction to Statistical Theory" Part I, II, 6th Ed, llmi Kitab Khana, Lahore, Pakistan.
12. Cochran, W.G. "Sampling Techniques".3rd Ed.
13. Pollard, A.H.. Yousuf, F. and Pollard G.M. (1982), "Demographic Techniques", Pergamon Press, Sydney.

STAT- 501 Elements of Statistics and Biometry (3Cr.Hrs.)

Course Contents:
Introduction to Biostatistics its scope and importance. Data types, variables; Categorical, numerical and censored data. Descriptive Statistics; Measure of central tendency; mean, median, mode. Measure of dispersion; Variance and standard deviation. Simple linear regression; model fitting. Correlation; correlation co-efficient, co-efficient of determination. Chi-square and T-test. Logistic regression. Logit transformations and their analysis, p values and its importance and role. Hypothesis testing.

STAT-502 Elements of Statistics (3 Cr.Hrs)

Learning Objectives:

To give the basic knowledge of Statistics to the students not majoring in Statistics

Intended Learning Outcomes:
After completion of this course the student should be able to:

- Have the knowledge of basic Statistics;
- Understand and differentiate between the types of data and variables.
- Interpret basic descriptive statistics.
- Apply the concepts and the techniques in their respective disciplines.

Course Contents:
Introduction to Statistics: Measures of Central Tendency; mean, median and mode; properties, usage, limitations and comparison through examples. Measure of dispersion. Index Numbers.

Sampling and sampling Distributions. Importance and scope of sampling. The probability and non-probability sampling. Hypothesis Testing; hypothesis testing procedure; Formation of research question into null and alternative hypotheses, P-values; Type I and Type II errors. Hypothesis testing about mean and difference of mean, t-test, z-test and Chi-square test.

Books Recommended:

1. Chaudhry, S.M.and Kamal, S. (1996), "Introduction to Statistical Theory" Parts I & II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.
2. Chaudhry, S.M.and Kamal, S. (1996), "Introduction to Statistical Theory" Parts I & II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.
3. Clark, G.M and Cooke, D. (1998), "A Basic Course in Statistics" 4th ed, Arnold, London.
4. Mclave, J.T., Benson, P.G. and Snitch, T. (2005) "Statistics for Business & Economics" 9th ed.Prentice Hall, New Jersey.
5. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "Probability and Statistics", 2nd ed. Schaums Outlines Series. McGraw Hill. NY.
6. Walpole, R.E., Myers, R.H and Myers, S.L. (1998), "Probability and Statistics for Engineers and Scientist" 6th edition, Prentice Hall, NY.

STAT-601 Basics of Statistics (3 Cr.Hrs)

Learning Objectives:
To give the sound knowledge of Statistics to the students not majoring in Statistics

Intended Learning Outcomes:
After completion of this course the student should be able to:

- Understand the essential tools of Statistics;
- Summarize and display the data through tables and graphs;
- Understand and differentiate between the types of data and variables;
- Apply the statistical techniques in their respective disciplines.

Course Contents:
Introduction to Statistics, Types of variables. Presentation of data: tabulation, Graphs and Charts and their interpretation. Descriptive Statistics, Measure of Central Tendency. Measure of dispersion. Regression and Correlation.
Introduction to Sampling and its Importance, Sampling Distributions of sampling, Statistics and parameters, sampling errors c. The probability and non-probability sampling.
Hypothesis Testing; The logic of hypothesis tests; translating a research question into null and alternative hypotheses ii. P-values; Type I and Type II errors. Testing of hypothesis about mean and difference of mean. Chi- square and T-test.

Books Recommended:

1. Chaudhry, S.M.and Kamal, S. (1996), "Introduction to Statistical Theory" Parts I & II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.
2. Chaudhry, S.M.and Kamal, S. (1996), "Introduction to Statistical Theory" Parts I & II, 6th ed, Ilmi Kitab Khana, Lahore, Pakistan.
3. Clark, G.M and Cooke, D. (1998), "A Basic Course in Statistics" 4th ed, Arnold, London.
4. Mclave, J.T., Benson, P.G. and Snitch, T. (2005) "Statistics for Business & Economics" 9th ed.Prentice Hall, New Jersey.
5. Spiegel, M.R., Schiller, J.L. and Sirinivasan, R.L. (2000) "Probability and Statistics", 2nd ed. Schaums Outlines Series. McGraw Hill. NY.
6. Walpole, R.E., Myers, R.H and Myers, S.L. (1998), "Probability and Statistics for Engineers and Scientist" 6th edition, Prentice Hall, NY.

Details of the Courses for M. S/ M.Phil in the programs other than Statistics

STAT- 701 Statistics in Education (3Cr.Hrs.)

Course Objectives:
To enable the students to comprehend the basic concepts of statistics, apply different statistical methods for data analysis. To carry analysis of correlation techniques on comparative data.

Learning Outcomes:
On successful completion of this course, students will be able to:

- Demonstrate fundamental concepts and procedures of descriptive and inferential statistics.
- Apply statistical methods for collection, description and analysis of data in a variety of contexts.
- Implement statistical methods to generalise from samples to populations.

Course Contents:

Statistical analysis in educational research, Frequency distribution. Types of research studies, variables types. Graphical methods of data representation, Normal probability curve & its importance.
Measures of central tendency, Mean, Median, Mode. Measures of variability; Quartiles, Variance and Standard deviation.
Liner regression and co-relation; Spearman's correlation and Pearson's correlation method.
Hypothesis Testing; Chi-square test and its application in hypotheses testing.

Reference Books:

1. Best, J.W. (2004) Research in Education, New Delhi: Prentice-Hall of India.
2. Garrett, Henry, E (2006). Statistics in Psychology and Education, National Book Foundation Islamabad.
3. Gay, L.R. (2007) Educational research: Competencies for Analysis and Application, New York: Macmillan Publishing Company.
4. Gravetter, F. J. and Wallnau, L. B. (2004) Statistics for the behavioural sciences (6th edition). USA: Thomson and Wadsworth.
5. Greenacre, M. (2007) Correspondence analysis in practice (2nd edition). Chapman and Hall/CR.
6. Howell, D. C. (2007) Statistical methods for psychology (6th edition). USA: Thomson and Wadsworth
7. Von Dalen, (1973), Understanding of Educational Research, McGraw-Hill; 3rd edition
8. Garret, H.E, (1982), Statistics in Education, Paragon International Publishers

STAT-702 Statistical Analysis (3 Cr.Hrs)

Course Objectives:

The main objective of this course is to provide the basics of statistics and enable the students to perform statistical analysis independently in their research work.

Intended Learning Outcomes:

Course Contents:

Basic Univariate statistical methods; Review of basic concepts, summary measures, hypothesis testing, t-test. Analysis of variance; Chi-Squared test; Regression and Correlation.

Multivariate statistical methods; Principal Concept analysis, Factor Analysis, Discriminant Analysis, Cluster analysis, Multidimensional Scaling, Hidden Markov models, Log linear Models, Bayesian Statistics.

Books Recommended:

1. Oakes. M.P.(1998,2005). "*Statistics for Corpus Linguistics*." Edinburgh Textbooks in Empirical Linguistics. Edinburgh University Press, Edinburgh.

2. Walpole, R.E. (1982). "*Introduction to Statistics*." 3rd Edition, Macmillan Publishing Co. Inc. New York.
3. Johnson, R.A Wichern, D.W. (2002). "*Applied Multivariate Statistical Analysis*" 5th Edition, Prentice Hall, New Jersey.
4. Clark, G.M. and Cooke, D. (1998), "A Basic Course in Statistics" 4th ed, Arnold, London.

STAT- 703 Mathematical Statistics (3Cr.Hrs.)

Course Objectives:
To provide solid mathematical foundations for statistical modeling and inferences.

Learning Outcomes:
On successful completion of this course, students will be able to:

- Demonstrate fundamental concepts and procedures of estimation and inferential statistics.
- Apply statistical methods for parameter estimation.
- Implement statistical methods for hypothesis testing.

Course Contents:

Fundamental concepts in the theory of estimation and hypothesis testing. Estimation of Parameters. Properties of Estimators: unbiasedness, consistency, sufficiency, efficiency, completeness. Cramer-Rao inequality, Rao-Blackwell and Lehmann - Scheffe Theorems. Methods of Estimation: Moments, Maximum likelihood, least-squares, minimum Chi- square and Bayes' method. Confidence intervals, the Neymann-Pearson framework, likelihood ratio tests.

Reference Books:

1. Hirai, A. S. (2012) Estimation of Parameters. Ilmi Kitab Khana Lahore.
2. Lehman, E.L. (2008). "Testing Statistical Hypotheses". Springler - Volga, New York.
3. Lindgren, B.W. (1998). "Statistical Theory". Chapman and Hall, New York.
4. Rao, C.R., (2009). "Linear Statistical Inference and its Applications", John Wiley, New York.
5. Stuart, A and Ord, J.K. (2009). Kendall's' "Advanced Theory of Statistics" Vol. II. Charles Griffin, London.
6. Welish, A. H. (2011) Aspects of Statistical Inference. Wiley.