CURRICULUM

OF

STATISTICS
BS, MS/M.Phil. and Ph.D.

(Revised 2017-18)

HIGHER EDUCATION COMMISSION

CURRICULUM DIVISION, HEC

Prof. Dr. Mukhtar Ahmed	Chairman, HEC
Prof. Dr. Arshad Ali	Executive Director, HEC
Mr. Muhammad Raza Chohan	Director General (Academics)
Dr. Muhammad Idrees	Director (Curriculum)
Mr. Hidayatullah Kasi	Deputy Director (Curriculum)
Mr. Rabeel Bhatti	Assistant Director (Curriculum)
Mr. Muhammad Faisal Khan	Assistant Director (Curriculum)

COURSE CONTENTS

1. Introduction
2. Frame Work for BS (4-years) in Statistics Layout
3. Model Scheme of Studies for BS (4-years) in Statistics
4. Aims and Objectives
5. List of General Courses
6. Elective Courses
7. Detail of Courses
8. Recommendations
9. Compulsory Courses
10. MS/M.Phil Statistics (2-years programme)
11. PhD (Statistics)
    Admission Requirement

Composed by: Mr. Zulfiqar Ali, HEC, Islamabad

PREFACE

The curriculum, with varying definitions, is said to be a plan of the teaching-learning process that students of an academic program are required to undergo to achieve some specific objectives. It includes scheme of studies, objectives & learning outcomes, course contents, teaching methodologies and assessment/ evaluation. Since knowledge in all disciplines and fields is expanding at a fast pace and new disciplines are also emerging; it is imperative that curricula be developed and revised accordingly.

University Grants Commission (UGC) was designated as the competent authority to develop, review and revise curricula beyond Class-XII vide Section 3, Sub-Section 2 (ii), Act of Parliament No. X of 1976 titled "Supervision of Curricula and Textbooks and Maintenance of Standard of Education". With the repeal of UGC Act, the same function was assigned to the Higher Education Commission (HEC) under its Ordinance of 2002, Section 10, Sub-Section 1 (v).

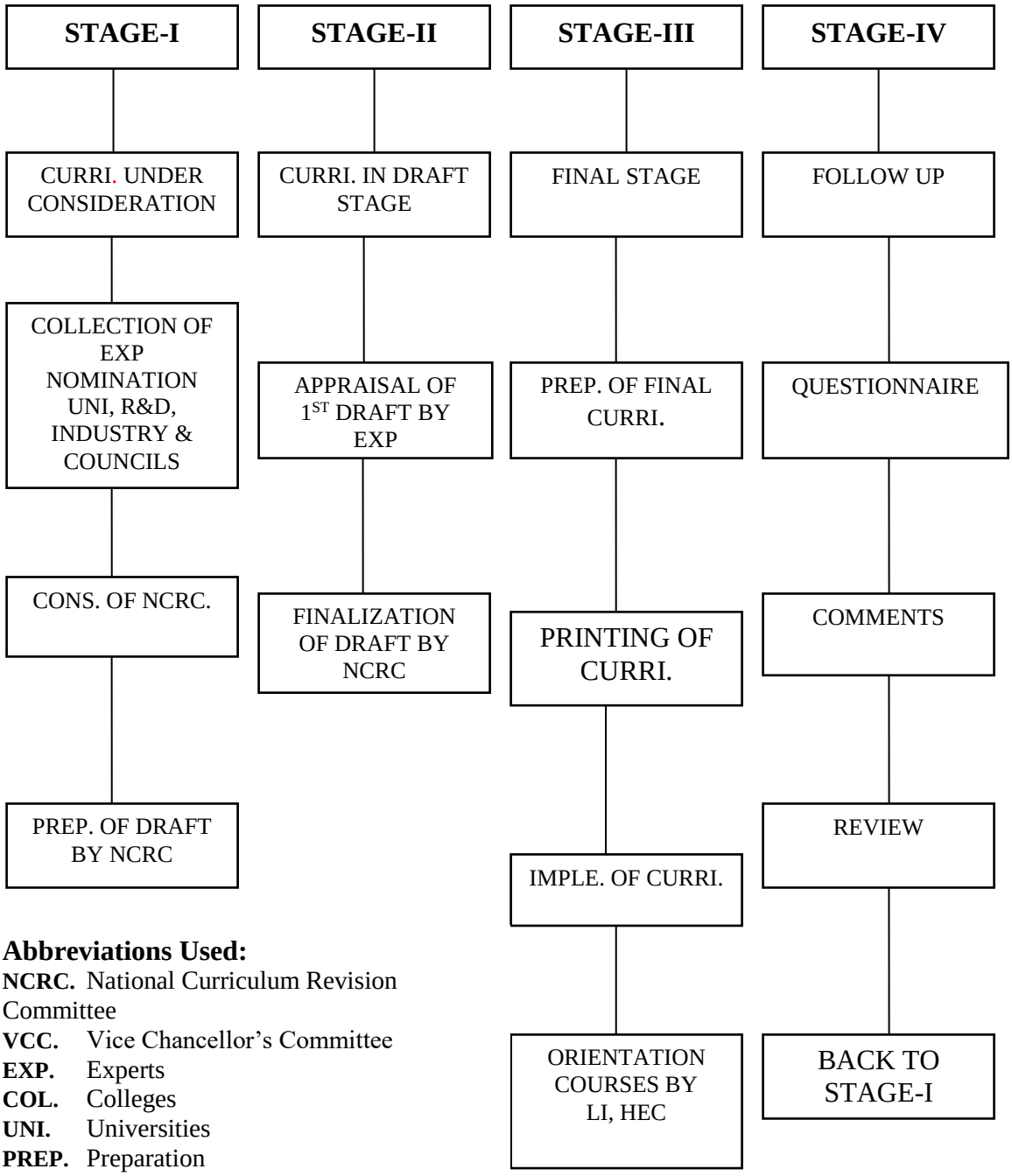
In compliance with the above provisions, the Curriculum Division of HEC undertakes the revision of curricula regularly through respective National Curriculum Revision Committees (NCRCs) which consist of eminent professors and researchers of relevant fields from public and private sector universities, R&D organizations, councils, industry and civil society by seeking nominations from their organizations.

In order to impart quality education which is at par with indigenous needs and international standards, HEC NCRCs have developed unified framework/ templates as guidelines for the development and revision of curricula in the disciplines of Basic Sciences, Applied Sciences, Social Sciences, Agriculture and Engineering.

It is hoped that this curriculum document, prepared by the respective NCRC's, would serve the purpose of meeting our national, social and economic needs, and it would also provide the level of competency specified in Pakistan Qualification Framework to make it compatible with international educational standards. The curriculum is also placed on the website of HEC
http://hec.gov.pk/english/services/universities/RevisedCurricula/Pages/default.aspx

(Muhammad Raza Chohan)
Director General (Academics)

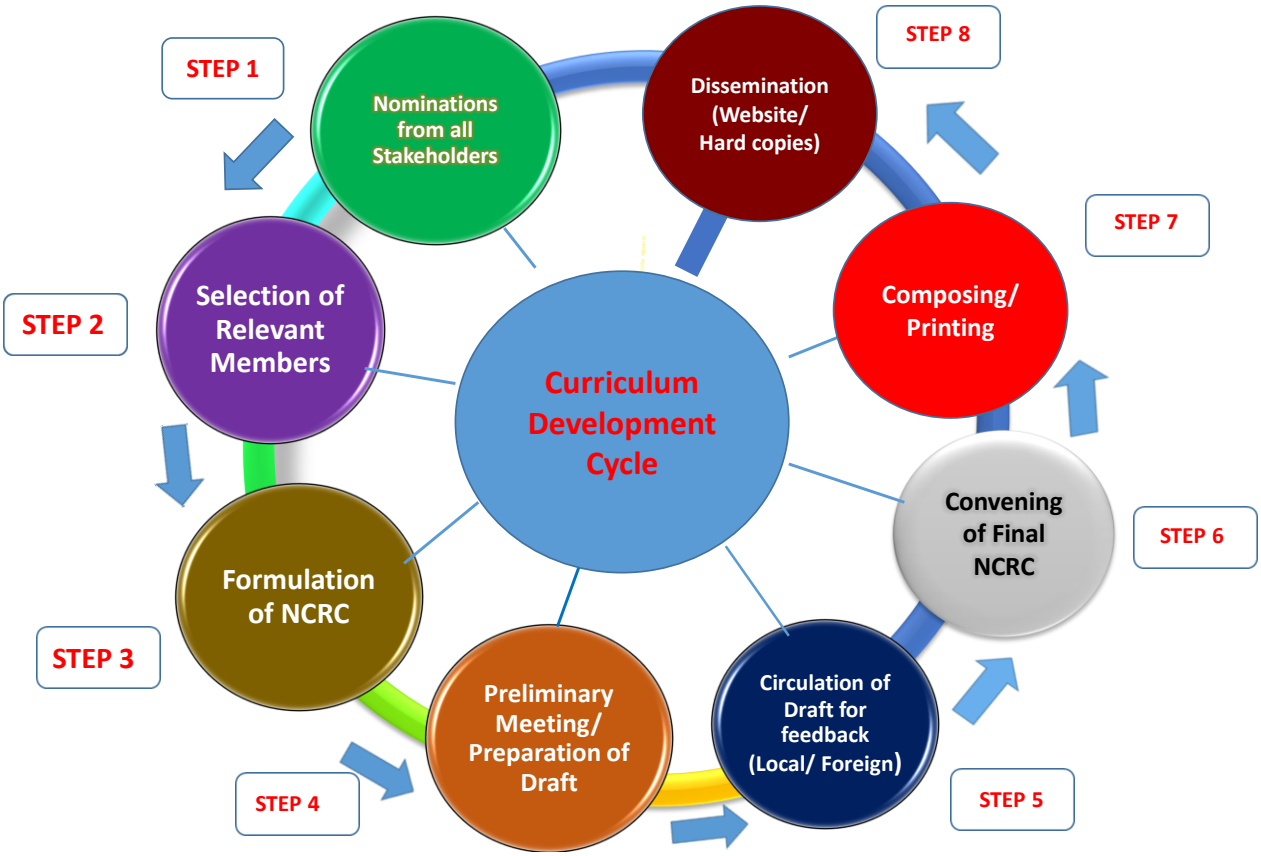
CURRICULUM DEVELOPMENT



Abbreviations Used:

NCRC. National Curriculum Revision Committee
VCC. Vice Chancellor's Committee
EXP. Experts
COL. Colleges
UNI. Universities
PREP. Preparation
REC. Recommendations
LI Learning Innovation
R&D Research & Development Organization
HEC Higher Education Commission
CONS: Constitution

CURRICULUM DEVELOPMENT CYCLE



Introduction:

This list of the participants who attended the meeting of National Curriculum Revision Committee (NCRC) meeting for the discipline of Statistics is as under below:

1.	Dr. Irshad Ahmad Arshad Chairman / Professor, Department of Statistics, Allama Iqbal Open University, H-8, Islamabad.	Convener
2.	Dr. Faisal Maqbool Zahid Associate Professor Department of Statistics, Government College University, Faisalabad.	Secretary
3.	Dr. Saud Ahmed Khan Assistant Professor, Department of Econometrics & Statistics, Pakistan Institute of Development Economics, Quaid-i-Azam Campus, Islamabad.	Member
4.	Dr. Muhammad Aslam Professor , Department of Mathematics & Statistics, Riphah International University, Sector I-14, Islamabad	Member
5.	Dr. Irshad Ahmad Arshad Chairman / Professor, Department of Statistics, Allama Iqbal Open University, H-8, Islamabad.	Member
6.	Dr. Tanweer ul Islam Assistant Professor, Department of Economics School of Social Science & Humanities, NUST, Sector H-12, Islamabad.	Member
7.	Dr. Zahid Asghar Associate Professor, Department of Statistics, Quaid-i-Azam University, Islamabad.	Member
8.	Dr. Bahrawar Jan Deputy Director General Pakistan Bureau of Statistics Statistics House, 21-Mauve Area, Sector G-9/1, Islamabad.	Member

9.	Dr. Rana Abdul Wajid Professor / Dean & Director Faculty of Basic Sciences, Centre for Mathematics & Statistical Sciences, Lahore School of Economics, Burki Road, Lahore.	Member
10.	Dr. Muhammad Azam Associate Professor Department of Statistics & CS, University of Veterinary & Animal Sciences, Lahore	Member
11.	Dr. Muhammad Mohsin Chairman / HoD Department of Statistics, COMSATS Institute of Information Technology, Defence Road, Off Raiwind Road, Lahore.	Member
12.	Ms. Munaza Zafar Bajwa Assistant Professor, Department of Statistics, Kinnaird College for Women, 93-Jail Road, Lahore.	Member
13.	Dr. Sharoon Hanook Chairperson / Assistant Professor, Department of Statistics, Room # S-438, Forman Christian College, Ferozpur Road, Lahore	Member
14.	Dr. Muhammad Amanullah Professor, Department of Statistics Bahauddin Zakariya University, Multan.	Member
15.	Dr. Muhammad Hanif Associate Professor Department of Mathematics & Statistics, PMAS Arid Agriculture University, Murree Road, Rawalpindi.	Member
16.	Dr. Shahid Kamal Professor / Dean College of Statistical & Actuarial Science, University of the Punjab, Quaid-i-Azam Campus, Lahore.	Member
17.	Dr. Muhammad Yaseen Assistant Professor, Department of Mathematics & Statistics, University of Agriculture, Faisalabad.	Member

18.	Dr. Fayyaz Ahmad Assistant Professor, Department of Statistics University of Gujrat, Gujrat.	Member
19.	Dr. Syed M. Shakil Ali Ghazali Chairman / Professor, Department of Statistics, The Islamia University of Bahawalpur, Bahawalpur.	Member
20.	Prof. Dr. Muhammad Hussain Tahir Professor, Department of Statistics, The Islamia University of Bahawalpur, Bahawalpur.	Member
21.	Dr. Uzma Nawaz Chairperson / Associate Professor, Department of Statistics The Women University Multan, LMQ Road, Katchery Chowk, Multan.	Member
22.	Dr. Mir Ghulam Hyder Talpur Professor, Department of Statistics University of Sindh, Jamshoro.	Member
23.	Prof. Dr. Mumtaz Hussain Mahar Dean / Professor, Faculty of Physical Sciences, Department of Statistics, Shah Abdul Latif University, Khairpur.	Member
24.	Prof. Dr. Velo Suthar Professor / Chairman, Department of Statistics, Sindh Agriculture University, Tandojam.	Member
25.	Dr. Amjad Ali Assistant Professor, Faculty of Basis & Social Sciences, Department of Statistics, Islamia College, Peshawar.	Member
26.	Dr. Asma Gul Assistant Professor, Department of Statistics, Shaheed Benazir Bhutto Women University, Charsadda Road, Peshawar.	Member

27.	Prof. Dr. Qamruz Zaman Professor, Faculty of Physical & Numerical Sciences, Department of Statistics, University of Peshawar, Peshawar.	Member
28.	Dr. Farhat Iqbal Associate Professor, Department of Statistics, University of Balochistan, Quetta.	Member
29.	Dr. Muhammad Zubair Khan Assistant Professor, Faculty of Arts & Basic Sciences, Department of Statistics, BUITEMS, Quetta.	Member
30.	Dr. Aamir Saghir Assistant Professor, Department of Statistics, Mirpur University of Science & Technology (MUST), Mirpur (AJK).	Member
31.	Dr. Muhammad Idrees Director (Curriculum) Higher Education Commission, Islamabad	Coordinator
32.	Mr. Rabeel Bhatti Assistant Director (Curriculum) Higher Education Commission, Islamabad	Coordinator

RECOMMENDATIONS

After thorough discussion, the participants of the National Curriculum Revision Committee in Statistics 2017 formulated the following recommendations for uniform and effective implementation of the HEC policies at national level.

1. Departments of Statistics in the universities should make efforts to interact with national and international statistical organizations such as PBS, industry and other users of statistics in the public and private sector.
2. Internship should be funded by the HEC and/or other funding agencies, and offered to the students.
3. All universities' departments should develop and maintain an internship / career services department to facilitate the internship students of Statistics.
4. The teaching of most of the courses requires the use of statistical packages. In this regard HEC should take positive steps to spare sufficient funds for purchasing the licensed statistical software (e.g., SPSS, Stata, Minitab etc.) for all universities.
5. Since there is a shortage of highly qualified statisticians in Pakistan. Therefore, allocating extra quota for statistics students to pursue higher education is needed.
6. The committee strongly recommends the creation of "Department of Biostatistics" for teaching and research guidance at all medical colleges/universities and the posts of biostatisticians in all hospitals/other institutions.
7. Practicum conducted during the course work should be in the form of case studies. The data published by different organizations may be used in such case studies.
8. A course on Statistics may be added in curriculum of FSc (Pre-Medical & Pre-Eng.) to prepare students for their professional education.
9. The department of Statistics in each university may establish a statistics consultancy center to attract potential researchers. HEC should provide technical and financial support to these research cells.
10. Refresher courses for the faculty should be regularly arranged by the HEC.
11. HEC should support universities for the development of computer labs, departmental libraries, students and staff participation in seminars, workshops, and conferences.
12. The department websites should be updated on a regular basis so that research interests of the faculty may become public.
13. PGD (Post Graduate Diploma) / Short courses should be offered by the universities/department of Statistics to the non-statisticians.

14. Professional ethics should be an integral part of the training of students at both the undergraduate and graduate level.
15. Since 4 year BS Programme is equivalent to old M.Sc. Programme in Statistics, therefore, the relevant recruitment rules for the post of BPS-17 may be amended by the concerned departments (FPSC, Establishment Division) and B.S. (Four year Programme) may be added in the eligibility criteria for the posts.
16. The department of Statistics in each university should make concrete efforts for establishing university-industry linkages for MS level research.

FRAME WORK FOR BS (4-YEAR) IN STATISTICS LAYOUT

Compulsory Requirements (the student has no choice)		**General Courses to be chosen from other departments**		**Discipline Specific Foundation Courses**	
9 courses		**7-8 courses**		**9-10 courses**	
25 Credit hours		**21-24 Cr. Hours**		**30-33 Credit hours**	
Subject	**Cr Hr**	**Subject**	**Cr Hr**	**Subject**	**Cr Hr**
1. English I	3	1. Introduction to Psychology	3	Introductory Statistics	3-4
2. English II	3	2. Introduction to Logic	3	Introduction to Probability & Probability Distributions	3-4
3. English III	3	3. Fundamentals of Economics	3	Basic Statistical Inference	3-4
4. Communication Skill	3	4. International Relations	3	Linear Algebra	3-4
5. Pakistan Studies	2	5. Basics of Sociology	3	Introduction to Regression and Analysis of Variance	3-4
6. Islamic Studies / Ethics	2	6. Introduction to Environmental Sciences	3	Exploratory Data Analysis and Visualization	3-4
7. Calculus-I	3	7. Principles of Management	3	Probability Distribution-1	3-4
8. Calculus-II	3	8. Business Administration 9. (Entrepreneurship)	3	Sampling Techniques-I	3-4
9. Introduction to Computer	**3**	OR * from the list of general courses given in Annexure on Page 5		Statistical Packages	**3-4**
TOTAL	**25**		**21**		**30**

Major courses including research project/internship		**Elective Courses within the major**	
11-13 courses		**4 courses**	
36-42 Credit hours		**12 Credit Hours**	
Subject	Cr Hr	**Subject**	**Cr Hr**
1. Regression Analysis	4	1. Operations Research	**3**
2. Design & Analysis of Experiment-I	4	2. Stochastic Process	**3**
3. Probability and Probability Distribution-II	3	3. Reliability Analysis	**3**
4. Sampling Techniques-II	4	4. Introduction to Time Series Analysis	**3**
5. Econometrics	4	5. Research Methodology	**3**
6. Design & Analysis of Experiment-II	4	6. Non-Parametric Methods	**3**
7. Statistical Inference-1	3	**OR** **** from the list of elective courses.**	
8. Multivariate Analysis-I	3		
9. Multivariate Analysis-II	4		
10. Population Studies	3		
11. Statistical Inference-II	4		
12. `Official Statistics	3		
13. Research Project / Internship	3		
TOTAL	46		**12**

MODEL SCHEME OF STUDIES FOR BS (4-YEAR) IN STATISTICS

Semester / Year	Name of Subject	Credits
First	Introductory Statistics	3
	Pakistan Studies	2
	English-I (Functional English)	3
	Calculus-I	3
	General-I	3
	General-II	3
		17
Second	Introduction to Probability Distributions	3
	Islamic Studies/Ethics	2
	English-II	3
	Calculus-II	3
	General-III	3
	General-IV	3
		17
Third	Basic Statistical Inference	3
	English-III	3
	Introduction to Computer and its Applications	3
	General-V	3
	General-VI	3
		15
Fourth	Exploratory Data Analysis and Visualization	3
	Introduction to Regression and Analysis of Variance	3
	Communication Skills	3
	Linear Algebra	3
	General-VII	3
		15
Fifth	Probability Distribution-1	3
	Sampling Technique-I	4
	Design & Analysis of Experiment-I	4
	Regression Analysis	4
	Statistical Packages	3
		18
Sixth	Probability Distribution-II	3
	Sampling Techniques-II	4
	Design & Analysis of Experiment-II	4
	Econometrics	4
	Official Statistics	3
		18

Seventh	Statistical Inference-1	3
	Applied Multivariate Analysis	4
	Time Series Analysis	3
	Elective I	3
	Elective-II	3
		16
Eight	Statistical Inference-II	3
	Population Studies	4
	Research Project / Internship	3
	Elective-III	3
	Elective-IV	3
		16
	Total	**132**

Note: 4 credit hours courses must include Lab. /Practical.

Aims and Objectives:

The major aims and objectives of the curriculum of Statistics are to adapt the curriculum to meet the international standards.

1. To provide a sound footing of the subject matter of statistical theory with applications, so that the students can pursue higher degrees and research in the field of statistics.

2. To train the students in the use of statistical software and techniques of data collection and analysis so that they can compete in the job market.

3. To involve the students in research project so that they can be better trained in the field of research.

4. To develop a solid foundation for the effective operational and strategic decisions based on statistical theory and methodology in almost every discipline.

* LIST OF GENERAL COURSES FOR STATISTICS

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

1. Business Administration (Entrepreneurship)
2. Human Resource Management
3. Environmental Sciences
4. Principles of Management & Marketing
5. Basic Financial Management

6. History of Human Civilization
7. Introduction to Biology
8. Foreign Language other than English
9. Introduction to Physics
10. Advanced Calculus
11. Introduction to Genetics
12. Introduction to Geography

or any other subject depending upon the expertise available.

** Elective Courses for BS (4-Year) Programme for Statistics

1. Operations Research
2. Stochastic Process
3. Reliability Analysis
4. Decision Theory
5. Robust Methods
6. Survival Analysis
7. Bio-Statistics
8. Data Mining
9. Actuarial Statistics-I
10. Actuarial Statistics-II
11. Mathematical Models and Simulation
12. Categorical Data Analysis
13. Numerical Methods
14. Bayesian Inference
15. Statistical Quality Control,

or any other subject depending upon the expertise available.

DETAIL OF COURSES

The proposed outlines of the BS (4-YEAR) programme in Statistics are as follows:

STAT- 101: Introductory Statistics

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:

- Acquire the basic knowledge of the discipline of Statistics.
- Understand and differentiate between the types of data and variables.
- Evaluate and Interpret basic descriptive statistics. Display and Interpret data graphs.

Course Contents:

The nature and scope of the Statistics, Variables and their types, Data and its sources, Scales of measurements, Tabulation and classification of data, Graphs and Charts: Stem-and leaf diagram, Box and Whisker plots and their interpretation. Measures of Central Tendency, Quantiles, Measures of Dispersion: Their properties, usage, limitations and comparison. Moments, Measures of Skewness and Kurtosis and Distribution shapes. Rates and ratios, Standardized scores.

Index numbers: construction and uses of index numbers, un-weighted index numbers (simple aggregative index, average of relative price index numbers), weighted index numbers (Laspayer's, Paasche's and Fisher's ideal index numbers), Consumer price index (CPI) and Sensitive Price Indicators

Recommended Books:

1. Clarke, G. M., & Cooke, D. (1978). *A basic course in statistics* (No. 519.5 C53).
2. Chaudhry, S.M. and Kamal, S. (2008), "*Introduction to Statistical Theory*" Parts I & II, 8th ed, Ilmi Kitab Khana, Lahore, Pakistan.
3. Mann, P. S. (2010) Introductory Statistics. Wiley.
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, R.E., Myers, R.H and Myers, S.L. (1998), "*Probability and Statistics for Engineers and Scientist*" 6th edition, Prentice Hall, NY.
6. Zaman, A. (2016), "Introduction to Statistics" Online access for book and related data sets.
   https://sites.google.com/site/introstats4muslims/textbook
   https://sites.google.com/site/introstats4muslims/excel.

STAT- 102: Introduction to Probability & Probability Distributions

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:

- Acquire the basic knowledge of probability and probability distribution.
- Understand the concepts of basic techniques of measuring the uncertainty problem.
- Analyze the problem of genetics finance and telecommunications by using probability techniques.

Course Contents:

Set theory and its operations, Probability Concepts, Addition and Multiplication Rules, Bivariate Frequency Tables, Joint and Marginal Probabilities, Conditional Probability and Independence, Bayes' Rule. Random Variables, Discrete Probability Distribution, Mean and Variance of a Discrete Random Variable, Bernoulli Trials, Properties, Applications and Fitting of Binomial, Poisson, Hypergeometric, Negative Binomial and Geometric Distributions. Continuous Random Variable, Probability Density Function and its Properties, Normal Distribution and its Properties, Standard Normal Curve.

Recommended Books:

1. Cacoullos, T. (2012). *Exercises in probability*. Springer Science & Business Media.
2. Mclave, J.T., Benson, P.G. and Snitch, T. (2005) "*Statistics for Business & Economics*" 9th Edition. Prentice Hall, New Jersey.
3. Santos, David (David A.) (2011). *Probability : an introduction*. Jones and Bartlett Publishers, Sudbury, Mass

4. Walpole, R.E., Myers, R.H and Myers, S.L. (2007), "*Probability and Statistics for Engineers and Scientist*" 7th edition, Prentice Hall, NY.

STAT- 202: Basic Statistical Inference

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:

- Acquire 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:

Sampling and sampling distribution of sample mean, proportion, difference between means and difference between proportions; Point and interval estimate properties of good point estimator; Testing of hypothesis for population mean, difference between population means and population proportion and difference between two population proportions, difference between means for paired data; Single population variance, ratio of two variances; Non-parametric methods: The sign test, Wilcoxon's signed rank test, Mann-Whitney U test, Median test, Run test, Kolmogrorov-Smirnov test, Kruskal-Wallis test, Median test for k-samples, Friedman test.

Pre-Requisite- STAT-102

Recommended Books:

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

STAT-204 Linear Algebra

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 analyze the structure of real-world problems and plan solution strategies. Solve the problems using appropriate tools.

Learning Outcomes:

- 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 modeling
- Analyze/interpret quantitative data verbally, graphically, symbolically and numerically.

Course Contents:

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.

Recommended Books:

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. Leon, J. S. (2015). *Linear Algebra with Applications*, 9th edition.
4. Seymour, L and Marc, L. (2006), *Linear Algebra, Schaum's Outline Series*, McGraw-Hill.
5. Strang, G. (2016). *Introduction to Linear Algrebra* , 5th edition.

STAT- 203: Introduction to Regression and Analysis of Variance

Course Objectives:

- To provide foundations of regression analysis.
- To provide basic knowledge and art of statistical data analysis
- To predict and draw inference about the parameters of the parameters of population.

Learning Outcomes:

- Explore more adequately the connection between theory of regression.
- Analysis of real world problems.
- Prediction of dependent variable.

Course Contents:

Relationship between variables, 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-101

Recommended Books:

1. Montgomery, D. C., Peck, E. A., and Vining, G. G. (2012). Introduction to linear regression analysis (Vol. 821). John Wiley and Sons.
2. Dielman, T. E. (2001). Applied regression analysis for business and economics. Pacific Grove, CA: Duxbury/Thomson Learning.
3. Rawlings, J. O., Pantula, S. G., and Dickey, D. A. (2001). Applied regression analysis: a research tool. Springer Science and Business Media.

STAT-401: Exploratory Data Analysis and Visualization (EDAV)

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:

Exploratory Data Analysis: Explore, Visualize, Analyze, Repeat. Selective data collective and data exploration. Data 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/
4. Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis (2nd Springer. http://ggplot2.org/book/; http://hadley.nz/

STAT- 204: Statistical Packages

Course Objectives:

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

Learning Outcomes:

- 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.

Recommended Books:

1. Ryan, B. F. and Joiner, B. L. (2001). Minitab handbook. Duxbury Press.
2. Holmes, W. H. and Rinaman, W. C. (2014). Introduction to SPSS. In Statistical Literacy for Clinical Practitioners (pp. 25-57). Springer, Cham.
3. Dalgaard, P. (2002) Introductory Statistics with R, Springer,
4. Verzani, J. (2005). Using R for Introductory Statistics, Chapman and Hall/ CRC press, Taylor and Francis.

STAT- 301: Probability Distributions- I

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:

Distribution function, Probability mass and density functions. 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, Moment generating and characteristic functions with their properties. Factorial Moments, Cummulants, L moments and their relationships. Probability distributions: Bernoulli, Binomial, Hypergeometric, Poisson, Negative binomial, Geometric, discrete uniform, Multinomial distribution. Normal approximation to binomial, Poisson and Hypergeometric distribution.

Pre-Requisite: STAT-102

Recommended Books:

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 Distributions,* 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- 303: Sampling Techniques-I

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:

- 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 of 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

Pre-Requisite: STAT-201

Recommended Books:

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.

and

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

STAT- 307: Regression Analysis

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:

- Students would have enough knowledge of regression analysis.
- Students will be able to understand the concept of basic assumption of regression and how to overcome these problems.
- It developed the skills of students to analyze 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-203

Recommended Books:

1. Montgomery, D. C., Peck, E. A., & Vining, G. G. (2012). Introduction to linear regression analysis (Vol. 821). John Wiley and Sons.
2. Rawlings, J. O., Pantula, S. G., and Dickey, D. A. (2001). Applied regression analysis: a research tool. Springer Science & Business Media.
3. Dielman, T. E. (2001). Applied regression analysis for business and economics. Pacific Grove, CA: Duxbury Thomson Learning.
4. Yan, X. and Zu, X. G. (2009) Linear Regression Analysis: Theory and Computing. World Scientific Publications.

STAT- 305: Design and Analysis of Experiments-I

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:

- 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 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. Incomplete block designs (IBD), balanced incomplete block designs (BIBD) and partially balanced incomplete block designs (PBIBD). Intra-block and Inter-block analysis of IBD.

Pre-Requisite: STAT-203

Recommended Books:

1. Gomez, K.A. and Gomez, A.A. (1984). *Statistical Procedures for Agricultural Research*, John Wiley & Sons, New York, USA.
2. Kehul, R.O. (2000). *Design of Experiments: Statistical Principles of Research Design and Analysis*, Duxbury/ Thomson Learning, New York, USA.
3. Montgomery, D.C. (2012). *Design and Analysis of Experiments*, John Wiley & Sons, New York, USA.
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.

STAT- 310: Non-Parametric Methods

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

Pre-Requisite: STAT-202

Recommended Books:

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. Lehman, E.L. (1973), *Nonparametric Statistical Methods, based on Ranks*, Holden-Day San Francesco
4. Maritz, J.S. (1995). *Distribution-Free Statistical Methods*, Chapman & Hall London
5. Sprint, P. (2007). *Applied Nonparametric Statistical Methods, 4th edition*, Chapman & Hall London

STAT- 302: Probability Distributions - II

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:

- 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 their properties; 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-301

Recommended Books:

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 Distributions,* 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- 304: Sampling Techniques-II

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:

- 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; non-response, their sources and bias and Randomized response.

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-303

Recommended Books:

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- 308: Econometrics

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.

Recommended Books:

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. Gujrati, D. (2004). “Basic Econometrics”, John Wiley, New York.
4. Koutsoyiannis, A. (1980), “Theory of Econometrics”, Macmillan.
5. Wonnacot, T.H. and Wonnacot R.J. (1998). “Econometrics”, John Wiley, New York

STAT- 306: Design and Analysis of Experiments-II

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. 2^k and 3^k 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-305

Recommended Books:

1. Gomez, K.A. and Gomez, A.A. (1984). *Statistical Procedures for Agricultural Research*, John Wiley & Sons, New York, USA.
2. Kehul, R.O. (2000). *Design of Experiments: Statistical Principles of Research Design and Analysis*, Duxbury/ Thomson Learning, New York, USA.
3. Montgomery, D.C. (2012). *Design and Analysis of Experiments*, John Wiley & Sons, New York, USA.

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.

STAT- 311: Population Studies

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

Construction of complete and abridged life tables, Different types of life tables, Graphs of l_x, q_x and e_x, Description and uses of life table columns.

Recommended Books:

1. Bogue, D.J. Arriagu, E.E., Anderson, D.L. (1993), "*Readings in Population Research Methodology", Vol. I-VIII*, United Nations Fund; Social Development Centre, Chicago.
2. Hinde, A., (1998). "*Demographic Method"*, Arnold New York.
3. Impagliazo, J. (1993), *Deterministic Aspects of Mathematical Demography*, Springer Verlag New York.
4. Jay Weinstein, Vijayan, K. Pillai, (2001) "*Demography: The Science of Population"*. Allyn & Bacon.1.
5. Keyfitz, N. (1983) "*Applied Mathematical Demography",* Springer Verlag N.Y.
6. Palmore, J.A; Gardner, R.W. (1994), "*Measuring Mortality Increase"*; East West Centre, Honolulu.
7. Pollard, A.H., Yousaf, F & Pollard, G.M. (1982), "*Demographic Techniques"*, Pergamon Press, Sydney.
8. Rukanuddin A.R. and Farooqi, M.N.I.., (1988), "*The State of Population in Pakistan – 1987"*, NIPS, Islamabad.

9. Govt. of Pakistan (1998), *National, Provincial and District census reports and other supplementary reports with respect to 1998 census*; PCO, Islamabad.
10. Pakistan Demographic Survey (2007), Govt. of Pakistan.
11. Publications of population census organizations.
12. United Nations (1990), "*World Population Monitoring 1989"*, UNFPA.
13. United Nations (1998), *"World Population Assessment"*, UNFPA; New York.
14. United Nations (1996), "*Added years of Life in Asia"*, ESCAP; U.N., Thailand.
15. Haupt, A., Kane, T. T., and Haub, C. (2011) PRB's Population Handbook.

STAT- 312: Population Models

Stationary population models, Population estimates and projections, Inter-censual estimates, Population projections through various methods. Theory of demographic transition, Stable and stationary population models, their applications and uses, Malthusian and post Malthusian theories of growth, 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

Recommended Books:

1. Bogue, D.J. Arriagu, E.E., Anderson, D.L. (1993), "*Readings in Population Research Methodology", Vol. I-VIII*, United Nations Fund; Social Development Centre, Chicago.
2. Hinde, A., (1998). "*Demographic Method"*, Arnold New York.
3. Impagliazo, J. (1993), *Deterministic Aspects of Mathematical Demography*, Springer Verlag New York.
4. Jay Weinstein, Vijayan, K. Pillai, (2001) "*Demography: The Science of Population"*. Allyn & Bacon.1.
5. Keyfitz, N. (1983) "*Applied Mathematical Demography",* Springer Verlag N.Y.
6. Palmore, J.A; Gardner, R.W. (1994), "*Measuring Mortality Increase"*; East West Centre, Honolulu.
7. Pollard, A.H., Yousaf, F & Pollard, G.M. (1982), "*Demographic Techniques"*, Pergamon Press, Sydney.
8. Rukanuddin A.R. and Farooqi, M.N.I.., (1988), "*The State of Population in Pakistan – 1987"*, NIPS, Islamabad.
9. Govt. of Pakistan (1998), *National, Provincial and District census reports and other supplementary reports with respect to 1998 census*; PCO, Islamabad.
10. Pakistan Demographic Survey (2007), Govt. of Pakistan.
11. Publications of population census organizations.
12. United Nations (1990), "*World Population Monitoring 1989"*, UNFPA.

13. United Nations (1998), *"World Population Assessment"*, UNFPA; New York.
14. United Nations (1996), "*Added years of Life in Asia"*, ESCAP; U.N., Thailand.
15. Haupt, A., Kane, T. T., and Haub, C. (2011) PRB's Population Handbook.

STAT- 401: Statistical Inference-I

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:

- Explain the notion of a parametric model and point estimation of the parameters of those models. Explain and apply approaches to include a measure of accuracy for estimation procedures and our confidence in them by examining the area of interval estimation.
- Asses the plausibility of pre-specified ideas about the parameters of a model by examining the area of 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, Invariance, completeness. Cramer-Rao inequality, Rao-Blackwell and Lehmann - Scheffe Theorems, Methods of Estimation: Moments, Maximum likelihood, least-squares, minimum Chi-square and Bayes' method.

Pre-Requisite: STAT-302

Recommended Books:

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- 402: Statistical Inference-II

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:

Interval Estimation: Pivotal and other methods of finding confidence interval, confidence interval in large samples, shortest confidence interval, optimum confidence interval. Bayes' Interval estimation

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-401

Recommended 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.

STAT- 403: Multivariate Analysis

Course Objectives:

- This course provides the fundamental knowledge of multivariate data and its applications in different fields of life.
- This course will introduce the students 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. Euclidean and statistical distance. Review of matrix algebra, quadratic form, Eigen analysis, spectral decomposition. Descriptive statistics for multivariate data, multivariate normal distribution and its properties, Methods for testing multivariate normality, Inference about mean vector, Inference about covariance matrices, One-way multivariate analysis of variance (MANOVA), profile analysis

Pre-Requisite: STAT-305

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- 402: Statistical Inference-II

Interval Estimation: Pivotal and other methods of finding confidence interval, confidence interval in large samples, shortest confidence interval, optimum confidence interval. Bayes' Interval estimation

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-401

Recommended Books:

1. Hogg, R.V. and Craig, A.T. (1996). "*Introduction to Mathematical Statistics".* Prentice Hall, New Jersey.
2. Hirai, A. S. (2012) Estimation of Parameters. Ilmi Kitab Khana Lahore.
3. Lehman, E.L. (2008). "*Testing Statistical Hypotheses".* Springler - Volga, New York.
4. Lindgren, B.W. (1998). "*Statistical Theory"*. Chapman and Hall, New York.
5. Mood, A.M. Gray Bill, F.A. and Boss, D.C. (1997). "*Introduction to the Theory of Statistics"*. McGraw Hill, New York.
6. Rao, C.R., (2009). *"Linear Statistical Inference and its Applications",* John Wiley, New York.
7. Stuart, A and Ord, J.K. (2009). *Kendall's' "Advanced Theory of Statistics" Vol. II.* Charles Griffin, London.
8. Welish, A. H. (2011) Aspects of Statistical Inference. Wiley.
9. Zacks, S. (1973), "*Parametric Statistical Inference",* John Wiley, New York.

STAT- 422: RESEARCH PROJECT / INTERNSHIP

Note: A separate and independent research project/internship 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 (BS)

STAT- 405: Research Methodology

Course Objectives:

- To understand some basic concepts of research and its methodologies
- To identify appropriate research problems
- To select and define appropriate research problems and parameters
- To organize and conduct research in more appropriate manner

Learning Outcomes:

- Understand general definition of research design
- Solve the problems in the fields of qualitative and quantitative research
- Plan and conduct research using an appropriate research design, keeping in view the ethical issues in the research
- Critically review and develop a complete research project

Course Contents:

Definition of Research, Types of Research: Quantitave and Qualitative research. Plagiarism and ethics of research. Selection of Problem, Search of References, Formation of Hypothesis and Procedure for its Testing, Research Design, Planning of Experiments and surveys to Test Hypothesis Objectivity, Principals of Experimental Design, Steps in Experimentation, Designing Questionnaire, Collection of Data, Data Analysis, Functional/causal 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. Qualitative Research: content analysis.

NOTE: Studying and reviewing standard survey questionnaires and preparation of a sample questionnaire and a scientific report.

Pre-Requisite: STAT-304

Recommended Books:

1. 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.
2. Panneerselvam, R. (2013). *Research Methodology.* Prentice Hall India.
3. Singh, Y.K. (2011). *Fundamental of Research Methodology and Statistics.* New Age International limited.
4. Daniel, P.S. and Sam, A.G. (2011). *Research Methodology.* Kalpaz Publications, Delhi.
5. Salkind, N.J. (2010). *Encyclopedia of Research Design.* Sage Publications, Inc.

6. Creswell, J.W. (2002). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches.* Sage Publications.

STAT-406: Operations Research

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:

- 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- 407: Stochastic Processes

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.
- Furthermore, Markov chains in discrete and continuous time as well as Possion 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:

Introduction, Generating Functions, Laplace Transforms, Differential-Difference Equations, Introduction to Stochastic Processes. Types of stochastic process, stationary process. Random Walk, Expected Duration of the Game, Markov Chains, Transition Probabilities, Classification of States and Chains, Markov processes of discrete and continuous State Space, Poisson Process and its Generalization, Pure Birth and Death Processes, Random process, Weiner process, Introduction to Brownian motion.

Recommended Books:

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- 408: Reliability Theory

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:

- Analyze 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, Life time 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 simulations, distribution-free and Bayes' methods in reliability, System reliability; series and parallel systems, Failure models, (k-out-of-m) New-better-than used models. Inferences for these models, Accelerated life testing

Recommended Books:

1. Jardine, A.K.S. and Tsang, A.H.C. (2013). *Maintenance, Replacement and Reliability: Theory and Applications*. 2nd edition. CRC Press.
2. Elsayed, E.A. (2012). *Reliability Engineering.* 2nd edition. John Wiley & Sons.
3. O'Connor, D.T. (2002). *Practical Reliability Engineering.* 4th edition. John Wiley & Sons.
4. Gertsbakh, I.B. (1989). *Statistical Reliability Theory*. Marcel Decker. New York.
5. Gertsbakh, I.B. (2009). *Reliability Theory: with applications to preventive maintenance*. Springer, India.

STAT- 409: Time Series Analysis

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:

- 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

Recommended Books:

1. Enders, W. (2004). Applied time series econometrics. *Hoboken: John Wiley and 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. Jonathan D. C. and Kung-Sik C. (2008): Time Series Analysis with Applications in R, Springer, USA.
6. Peter J. B and Richard A. D (2002): Introduction to Time Series and Forecasting, Second Edition, Springer, USA.

STAT- 411: Robust Methods

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:

- 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- 412: Official Statistics

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:

Introduction to official statistics, statistical systems and international standards, set up of national and provincial statistical organizations in Pakistan, its role in development of statistics, working and publications.

Sources of official statistics, National Database Registration Authority (NADRA) and its role, Economic Statistics producers, International classification and standards.

Use of Statistics in administration and planning concepts and evaluation of GDP, GNP, NNP, balance of Trade and payments. Measurements of income distribution, prices and price mechanisms. Deflation and Inflation of series, Industrial quantum index, National sample surveys and census conducted in Pakistan.

Note: Visit of major Statistical Organizations should be a part of the course. Alternatively, the department may invite experts from various statistical organizations.

Suggested Reports:

1. Hansen M.H. (1980). Progress and Problems in Survey Methods and Theory. IIlustrated by the work of U.S. Bureau of the Census, U.S. Department of Commerce; A Monograph.
2. NIPA (1962). Administrative uses of Statistics. NIPA Karachi.
3. Statistical Institute for Asia and Pacific SIAP (1984). Training of Trainers in Statistical Operations and Procedures. Part-I, II UNDP, Tokyo.
4. Statistics Division (1979). Retrospect, Perspective and Prospect. Islamabad.
5. Statistics Division Activity Report (1988-89). Government of Pakistan, Islamabad.

*Various Publications of PBS, State Bank of Pakistan, Ministry of Finance, etc.

STAT- 413: Survival Analysis

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:

Introduction to survival analysis with some important basic definition of statistical quantities, terminologies and notation of survival and hazard function, Censored Data and its three types, truncation ; importance and scope of the survival analysis.

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.

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. and Klein, M. (2012). *Survival Analysis: A self learning text*. 3rd edition. Springer, New York, NY, USA.
4. Gjessing, H., Aalen, O. O. and Borgan, O. (2012). *Survival and Event history analysis*. Springer 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- 414: Biostatistics

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:

Introduction to the basic concepts and terminology of Biostatistics, types of variables, populations, target populations and sampled population: Role of sampling in biostatistics, Sample size estimation. Contingency table analysis, Fisher's exact test, 2x2 tables, 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

Recommended Books:

1. Sullivan, M.L. (2018). *Essentials of Biostatistics in Public Health*. 3rd edition. Jones and Bartlett Learning, Burlington, MA, USA.

2. Antonisamy, B. Premkumar, P. and Christopher, S. (2017). *Principles and Practice of Biostatistics*. 1st edition. Elsevier, India.
3. Alfassi Z. B., Boger, Z. and Ronen, Y. (2005): *Statistical Treatment of Analytical Data*. Blackwell Science, USA.
4. Daniel, W.W. (2010). *Biostatistics: A Foundation for the Health Sciences*. 6th edition. John Wiley, New York. NY, USA.
5. Dunn, G. and Everit, B. (1995). *Clinical Biostatistics*. Edward Arnold, London, UK.
6. Zar, J. (2000). *Biostatistical Analysis.* 5th Edition. John Wiley & Sons, New York, NY, USA.

STAT- 415: Data Mining

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.

Recommended Books:

1. Benson and Smith, S.J. (1997). "*Data Warehousing, Data Mining'*, and OLAP. McGraw-Hill.
2. Bramer M (2007): *Principles of Data Mining*. Springer-Verlag London Limited UK.
3. Breiman, L. Friedman, J.H. Olshen, R.A. and Stone, C.J. (1984). "*Classification and Regression Trees"* Wadsworth and Brooks/Cole.
4. Han, J., Kamber, J. Pei, J., and Burlington, M. A. (2012) Data mining: concepts and techniques. Haryana, India.
5. Han, J. and Camber, M. (2000). Data Mining; "*Concepts and Techniques*". Morgan Gaufmann.
6. Mitchell, T.M. (1997). *"Machine Learning*". McGraw-Hill.
7. 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.
8. Ripley, B.D. (1996). *"Pattern Recognition and Neural Networks*". Cambridge University Press.
9. Suh, S. C. (2012) Practical applications of data mining. Suh. Publisher
10. Tan P., Steinbach M. & Kumar V. (2006): *Introduction to Data Mining.* Addison Wesley, New York.

STAT- 416: Actuarial Statistics – I

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.

Course Contents:

Interest Rate Theory: Simple interest rate, Compound interest rate, Discount interest rate, Force of Interest, Real and Money Interest. Annuities: Description of annuities, Term annuity, Deferred annuity, Non-level annuities, Continuous annuities. Introduction to Actuarial Science, Role of Actuaries: Business, Finance, Stock Markets, Banks and other Financial Institutions. The role of Actuaries in Government Departments: SECP, State Bank, Employee Benefits Management. Insurance and Assurance, Types of Insurance: Life Insurance, Health Insurance, Motor Insurance, Businesses and Pension Fund. Islamic Mode of Insurance / Takaful. Life Insurance Contract: Define simple insurance contracts and devolve the formulae for mean and variance of the present values of the payments under these contracts, Whole life assurance, Term assurance, Pure endowment assurance, endowment assurance and critical ill-health assurance including assurances where the benefits are deferred also derive their mean and variances Define the symbols $A_x, A_{x:\overline{n}|}, A^{1}_{x:\overline{n}|}, A_{x:\overline{n}|}{}^{1}$ and their select and continuous equivalents.

Recommended books:

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

STAT- 417: Actuarial Statistics – II

Course Objectives:

- Developing an understanding of the mathematical concepts and techniques that are used to model and value cash flows contingent on survival, death and other uncertain events.
- Building mathematical foundations of life insurance and superannuation models.

Learning Outcomes:

- Understanding the Life Tables, Types and Computations.
- Understanding the Theories of Mortality, Analytical Laws and Projections.
- Develop and analyze the pension and benefit strategies that are equitable and meet the needs of diverse communities.

Course Contents:

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.

Recommended books:

1. Allen, et al. (2013). *Retirement Plans: 401(k)s, IRAs, and Other Deferred Compensation Approaches,* McGraw-Hill, 11th Edition.
2. Benjamin, B. and Pollard, J.H. (2015). The Analysis of Mortality and other Actuarial Statistics, Society of Actuaries, 3rd Edition.
3. Booth, P.M. et al. (1999). Modern Actuarial Theory and Practice, Chapman & Hall.
4. Bowers, N.L. Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J. (1997). Actuarial Mathematics, Society of Actuaries, 2nd Edition.

5. Gerber, H.U. (1997). Life Insurance Mathematics, Springer-Verlag, 3rd Edition.
6. McGill, et al. (2010). *Fundamentals of Private Pensions*, Oxford University Press, 9th Edition.
7. Yamamoto, D.H. (2015). *Fundamentals of Retiree Group Benefits*, ACTEX, 2nd Edition.

STAT- 418: Mathematical Modeling and Simulation

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:

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: importance sampling for integration, control and antithetic variables.

Recommended Books:

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. Velten, K. (2009). Mathematical modeling and simulation. Wiley VCH, Germany.

STAT- 419: Categorical Data Analysis

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, 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, 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.

Poisson regression model, Poisson regression for rates, Log linear models for 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. Hosmer D. W. and Lemeshow S. (2004). *Applied Logistic Regression.* John Wiley & Sons.
4. Collett D. (2003). *Modeling Binary Data*. Champman and Hall/CRC.
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- 422: Bayesian Inference

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.

STAT- 423: Statistical Quality Control

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:

- 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

Recommended Books:

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, US**A**

RECOMMENDATIONS:

The following recommendations were made by the committee to enhance the teaching and learning of Statistics:

17. Departments of Statistics in the universities should make efforts to interact with national and international statistical organizations such as PBS, industrial and other spheres of public and private sectors where voluminous statistical data is awaiting data mining and future/current policy developments.
18. Internship should be funded by the HEC and/or other funding agencies, and offered to the students.
19. All universities departments should develop and maintain an internship / career services department to facilitate the internship students of Statistics.
20. The teaching of most of the courses requires the use of statistical packages. In this regard HEC should take positive steps to spare sufficient funds for purchasing the licensed statistical software (e.g., SPSS, Stata, Minitab, SAS, EViews, Matlab, Mathematica, Statistix etc.) for all universities.
21. The subject of Statistics should be categorically considered under the umbrella of social sciences.
22. The committee strongly recommends the creation of “Department of Biostatistics” for teaching and research guidance at all medical colleges/universities and the posts of biostatisticians in all hospitals/other institutions.
23. Practicum conducted during the course work should be in the form of case studies. Different data collection agencies/organizations should be encouraged to share/ disseminate the data among the Statistics departments of universities for having useful analysis and predictions from this valuable information.
24. A course on Statistics may be added in curriculum of FSc (Pre-Medical and Pre-Eng.) to prepare students for their professional education.
25. The department of Statistics in each university may establish a statistics consultancy center to attract potential researchers. HEC should provide technical and financial support to these research cells.
26. Refresher courses for the faculty with a special focus on the faculty of affiliated colleges of the universities should be regularly arranged by the HEC.
27. HEC should support universities for the development of computer labs, departmental libraries, students and staff participation in seminars, workshops, and conferences.

28. HEC should provide financial support for publishing the research work in well reputed impact factor international journals.
29. Statistics as major subject must be the eligibility criteria for the jobs requiring statistical expertise like statistical officers in different department.
30. The department websites should be updated on a regular basis so that research interests of the faculty may become public.
31. Short courses / Post Graduate Diploma (PGD) should be offered by the universities/department of Statistics to the non-statisticians/researchers in other disciplines.
32. Professional ethics should be an integral part of the training of students at both the undergraduate and graduate level.
33. The department of Statistics in each university should make concrete efforts for establishing university-industry linkages for MS/MPhil/PhD level research.

COMPULSORY COURSES IN ENGLISH FOR BS (4 YEAR) IN BASIC & SOCIAL SCIENCES

English I (Functional English)

Objectives: Enhance language skills and develop critical thinking.

Course Contents:

Basics of Grammar
Parts of speech and use of articles
Sentence structure, active and passive voice
Practice in unified sentence
Analysis of phrase, clause and sentence structure
Transitive and intransitive verbs
Punctuation and spelling

Comprehension

Answers to questions on a given text

Discussion

General topics and every-day conversation (topics for discussion to be at the discretion of the teacher keeping in view the level of students)

Listening

To be improved by showing documentaries/films carefully selected by subject teachers

Translation skills

Urdu to English

Paragraph writing

Topics to be chosen at the discretion of the teacher

Presentation skills

Introduction

Note: Extensive reading is required for vocabulary building

Recommended Books:

1. **Functional English**

a) Grammar

1. Practical English Grammar by A.J. Thomson and A.V. Martinet. Exercises 1, third edition, Oxford University Press, 1997. ISBN 0194313492
2. Practical English Grammar by A.J. Thomson and A.V. Martinet. Exercises 2, third edition, Oxford University Press, 1997. ISBN 0194313506

b) Writing

1. Writing Intermediate by Marie-Christine Boutin, Suzanne Brinand and Francoise Grellet., Oxford Supplementary Skills, Fourth Impression, 1993. ISBN 0 19 435405 7 Pages 20-27 and 35-41.

c) Reading/Comprehension

1. Reading Upper Intermediate Brain Tomlinson and Rod Ellis, Oxford Supplementary Skills, Third Impression, 1992. ISBN 0 19 453402 2

d) Speaking

English II (Communication Skills)

Objectives: Enable the students to meet their real life communication needs.

Course Contents:

Paragraph writing
Practice in writing a good, unified and coherent paragraph

Essay writing
Introduction

CV and job application
Translation skills
Urdu to English

Study skills
Skimming and scanning, intensive and extensive, and speed reading, summary and précis writing and comprehension

Academic skills
Letter/memo writing, minutes of meetings, use of library and internet

Presentation skills
Personality development (emphasis on content, style and pronunciation)

Note: documentaries to be shown for discussion and review

Recommended Books:
Communication Skills

a) Grammar

1. Practical English Grammar by A.J. Thomson and A.V. Martinet, Exercises 2, third edition, Oxford University Press, 1986. ISBN 0 19 431350 6

b) Writing

1. Writing. Intermediate by Marie-Chrisitine Boutin, Suzanne Brinand and Francoise Grellet. Oxford Supplementary Skills. Fourth Impression 1993. ISBN 019 435405 7 Pages 45-53 (note taking).
2. Writing. Upper-Intermediate by Rob Nolasco. Oxford Supplementary Skills. Fourth Impression 1992. ISBN 0 19 435406 5 (particularly good for writing memos, introduction to presentations, descriptive and argumentative writing).

c) Reading

1. Reading Advanced Brian Tomlinson and Rod Ellis, Oxford Supplementary Skills, Third Impression, 1991. ISBN 0 19 453403 0
2. Reading and Study Skills by John Langan
3. Study Skills by Richard Yorky.

English III (Technical Writing and Presentation Skills)

Objectives: Enhance language skills and develop critical thinking

Course Contents:
Presentation skills

Essay writing

Descriptive, narrative, discursive, argumentative

Academic writing

How to write a proposal for research paper/term paper

How to write a research paper/term paper (emphasis on style, content, language, form, clarity, consistency)

Technical Report writing

Progress report writing

Note: Extensive reading is required for vocabulary building

Recommended Books:

Technical Writing and Presentation Skills

a) **Essay Writing and Academic Writing**

1. Writing Advanced by Ron White, Oxford Supplementary Skills. Third Impression 1992, ISBN 0 19 435407 3 (particularly suitable for discursive, descriptive, argumentative and report writing)
2. College Writing Skills by John Langan. McGraw-Hill Higher Education. 2004.
3. Patterns of College Writing (4th edition) by Laurie G. Kirszner and Stephen R. Mandell. St. Martin's Press.

b) Presentation Skills

c) Reading

The Mercury Reader, a Custom Publication, Compiled by norther, Illinois University, General Editors: Janice Neulib; Kathleen Shine Cain; Stephen Ruffus and Maurice Scharton. (A reader which will give students exposure to the best of twentieth century literature, without taxing the taste of engineering students)

Annexure "B"

Pakistan Studies (Compulsory)

Introduction/Objectives:

- Develop vision of historical perspective, government, politics, contemporary Pakistan, ideological background of Pakistan.
- Study the process of governance, national development, issues arising in the modern age and posing challenges to Pakistan.

Course Outline:

1. **Historical Perspective**
   a. Ideological rationale with special reference to Sir Syed Ahmed Khan, Allama Muhammad Iqbal and Quaid-e-Azam Muhammad Ali Jinnah.
   b. Factors leading to Muslim separatism
   c. People and Land
      i. Indus Civilization
      ii. Muslim advent
      iii. Location and geo-physical features.
2. **Government and Politics in Pakistan**
   Political and constitutional phases:
   a. 1947-58
   b. 1958-71
   c. 1971-77
   d. 1977-88
   e. 1988-99
   f. 1999 onward
3. **Contemporary Pakistan**
   a. Economic institutions and issues
   b. Society and social structure
   c. Ethnicity
   d. Foreign policy of Pakistan and challenges
   e. Futuristic outlook of Pakistan

Recommended Books:

1. Burki, Shahid Javed. *State & Society in Pakistan,* The Macmillan Press Ltd 1980.
2. Akbar, S. Zaidi. *Issue in Pakistan's Economy.* Karachi: Oxford University Press, 2000.
3. S.M. Burke and Lawrence Ziring. Pakistan's Foreign policy: An Historical analysis. Karachi: Oxford University Press, 1993.
4. Mehmood, Safdar. *Pakistan Political Roots & Development.* Lahore, 1994.
5. Wilcox, Wayne. *The Emergence of Bangladesh.,* Washington: American Enterprise, Institute of Public Policy Research, 1972.
6. Mehmood, Safdar. *Pakistan Kayyun Toota,* Lahore: Idara-e-Saqafat-e-Islamia, Club Road, nd.

7. Amin, Tahir. *Ethno - National Movement in Pakistan,* Islamabad: Institute of Policy Studies, Islamabad.
8. Ziring, Lawrence. *Enigma of Political Development.* Kent England: WmDawson & sons Ltd, 1980.
9. Zahid, Ansar. *History & Culture of Sindh.* Karachi: Royal Book Company, 1980.
10. Afzal, M. Rafique. *Political Parties in Pakistan,* Vol. I, II & III. Islamabad: National Institute of Historical and cultural Research, 1998.
11. Sayeed, Khalid Bin. *The Political System of Pakistan.* Boston: Houghton Mifflin, 1967.
12. Aziz, K.K. *Party, Politics in Pakistan,* Islamabad: National Commission on Historical and Cultural Research, 1976.
13. Muhammad Waseem, *Pakistan under Martial Law*, Lahore: Vanguard, 1987.
14. Haq, Noor ul. *Making of Pakistan: The Military Perspective.* Islamabad: National Commission on Historical and Cultural Research, 1993.

Annexure "C"

ISLAMIC STUDIES
(Compulsory)

Objectives:

This course is aimed at:

1 To provide Basic information about Islamic Studies
2 To enhance understanding of the students regarding Islamic Civilization
3 To improve Students skill to perform prayers and other worships
4 To enhance the skill of the students for understanding of issues related to faith and religious life.

Detail of Courses:

Introduction to Quranic Studies

1) Basic Concepts of Quran
2) History of Quran
3) Uloom-ul -Quran

Study of Selected Text of Holly Quran

1) Verses of Surah Al-Baqra Related to Faith(Verse No-284-286)
2) Verses of Surah Al-Hujrat Related to Adab Al-Nabi (Verse No-1-18)
3) Verses of Surah Al-Mumanoon Related to Characteristics of faithful (Verse No-1-11)
4) Verses of Surah al-Furqan Related to Social Ethics (Verse No.63-77)
5) Verses of Surah Al-Inam Related to Ihkam(Verse No-152-154)

Study of Selected Text of Holly Quran

1) Verses of Surah Al-Ihzab Related to Adab al-Nabi (Verse No.6,21,40,56,57,58.)
2) Verses of Surah Al-Hashar (18,19,20) Related to thinking, Day of Judgment
3) Verses of Surah Al-Saf Related to Tafakar,Tadabar (Verse No-1,14)

Seerat of Holy Prophet (S.A.W) I

1) Life of Muhammad Bin Abdullah (Before Prophet Hood)
2) Life of Holy Prophet (S.A.W) in Makkah
3) Important Lessons Derived from the life of Holy Prophet in Makkah

Seerat of Holy Prophet (S.A.W) II

1) Life of Holy Prophet (S.A.W) in Madina
2) Important Events of Life Holy Prophet in Madina
3) Important Lessons Derived from the life of Holy Prophet in Madina

Introduction to Sunnah

1) Basic Concepts of Hadith
2) History of Hadith
3) Kinds of Hadith
4) Uloom –ul-Hadith
5) Sunnah & Hadith
6) Legal Position of Sunnah

Selected Study from Text of Hadith

Introduction to Islamic Law & Jurisprudence

1) Basic Concepts of Islamic Law & Jurisprudence
2) History & Importance of Islamic Law & Jurisprudence
3) Sources of Islamic Law & Jurisprudence
4) Nature of Differences in Islamic Law
5) Islam and Sectarianism

Islamic Culture & Civilization

1) Basic Concepts of Islamic Culture & Civilization
2) Historical Development of Islamic Culture & Civilization
3) Characteristics of Islamic Culture & Civilization
4) Islamic Culture & Civilization and Contemporary Issues

Islam & Science

1) Basic Concepts of Islam & Science
2) Contributions of Muslims in the Development of Science
3) Quran & Science

Islamic Economic System

1) Basic Concepts of Islamic Economic System
2) Means of Distribution of wealth in Islamic Economics
3) Islamic Concept of Riba
4) Islamic Ways of Trade & Commerce

Political System of Islam

1) Basic Concepts of Islamic Political System
2) Islamic Concept of Sovereignty
3) Basic Institutions of Govt. in Islam

Islamic History

1) Period of Khlaft-E-Rashida
2) Period of Ummayyads
3) Period of Abbasids

Social System of Islam

1) Basic Concepts Of Social System Of Islam
2) Elements Of Family
3) Ethical Values Of Islam

Recommended Books:

1) Hameed ullah Muhammad, "Emergence of Islam" , IRI, Islamabad
2) Hameed ullah Muhammad, "Muslim Conduct of State"
3) Hameed ullah Muhammad, 'Introduction to Islam
4) Mulana Muhammad Yousaf Islahi,"
5) Hussain Hamid Hassan, "An Introduction to the Study of Islamic Law" leaf Publication Islamabad, Pakistan.
6) Ahmad Hasan, "Principles of Islamic Jurisprudence" Islamic Research Institute, International Islamic University, Islamabad (1993)
7) Mir Waliullah, "Muslim Jurisprudence and the Quranic Law of Crimes" Islamic Book Service (1982)
8) H.S. Bhatia, "Studies in Islamic Law, Religion and Society" Deep & Deep Publications New Delhi (1989)
9) Dr. Muhammad Zia-ul-Haq, "Introduction to Al Sharia Al Islamia" Allama Iqbal Open University, Islamabad (2001)

Note: One course will be selected from the following three courses of Mathematics.

COMPULSORY MATHEMATICS COURSES FOR BS (4 YEAR)

(FOR STUDENTS NOT MAJORING IN MATHEMATICS)

1. MATHEMATICS I (ALGEBRA)

Prerequisite(s): Mathematics at secondary level

Credit Hours: 3 + 0

Specific Objectives of the Course:
To prepare the students, not majoring in mathematics, with the essential tools of algebra to apply the concepts and the techniques in their respective disciplines.

Course Outline:

Preliminaries: Real-number system, complex numbers, introduction to sets, set operations, functions, types of functions.

Matrices: Introduction to matrices, types, matrix inverse, determinants, system of linear equations, Cramer's rule.

Quadratic Equations: Solution of quadratic equations, qualitative analysis of roots of a quadratic equations, equations reducible to quadratic equations, cube roots of unity, relation between roots and coefficients of quadratic equations.

Sequences and Series: Arithmetic progression, geometric progression, harmonic progression.

Binomial Theorem: Introduction to mathematical induction, binomial theorem with rational and irrational indices.

Trigonometry: Fundamentals of trigonometry, trigonometric identities.

Recommended Books:

Dolciani MP, Wooton W, Beckenback EF, Sharron S, *Algebra 2 and Trigonometry*, 1978, Houghton & Mifflin, Boston (suggested text)

Kaufmann JE, College *Algebra and Trigonometry*, 1987, PWS-Kent Company, Boston

Swokowski EW, *Fundamentals of Algebra and Trigonometry* (6th edition), 1986, PWS-Kent Company, Boston

2. MATHEMATICS II (CALCULUS)

Prerequisite(s): Mathematics I (Algebra)

Credit Hours: 3 + 0

Specific Objectives of the Course:

To prepare the students, not majoring in mathematics, with the essential tools of calculus to apply the concepts and the techniques in their respective disciplines.

Course Outline:

Preliminaries: Real-number line, functions and their graphs, solution of equations involving absolute values, inequalities.

Limits and Continuity: Limit of a function, left-hand and right-hand limits, continuity, continuous functions.

Derivatives and their Applications: Differentiable functions, differentiation of polynomial, rational and transcendental functions, derivatives.
Integration and Definite Integrals: Techniques of evaluating indefinite integrals, integration by substitution, integration by parts, change of variables in indefinite integrals.

Recommended Books:

1. Anton H, Bevens I, Davis S, *Calculus: A New Horizon* (8th edition), 2005, John Wiley, New York
2. Stewart J, *Calculus* (3rd edition), 1995, Brooks/Cole (suggested text)
3. Swokowski EW, *Calculus and Analytic Geometry*, 1983, PWS-Kent Company, Boston
4. Thomas GB, Finney AR, *Calculus* (11th edition), 2005, Addison-Wesley, Reading, Ma, USA

3. MATHEMATICS III (GEOMETRY)

Prerequisite(s): Mathematics II (Calculus)

Credit Hours: 3 + 0

Specific Objectives of the Course:
To prepare the students, not majoring in mathematics, with the essential tools of geometry to apply the concepts and the techniques in their respective disciplines.

Course Outline:
Geometry in Two Dimensions: Cartesian-coordinate mesh, slope of a line, equation of a line, parallel and perpendicular lines, various forms of equation of a line, intersection of two lines, angle between two lines, distance between two points, distance between a point and a line.

Circle: Equation of a circle, circles determined by various conditions, intersection of lines and circles, locus of a point in various conditions.
Conic Sections: Parabola, ellipse, hyperbola, the general-second-degree equation

Recommended Books:

1. Abraham S, Analytic Geometry, Scott, Freshman and Company, 1969
2. Kaufmann JE, College *Algebra and Trigonometry*, 1987, PWS-Kent Company, Boston
3. Swokowski EW, *Fundamentals of Algebra and Trigonometry* (6^{th} edition), 1986, PWS-Kent Company, Boston

COURSE FOR NON-STATISTICS MAJOR IN SOCIAL SCIENCES

Title of subject	:	Introduction of Statistics
Discipline	:	BS (Social Sciences).
Pre-requisites	:	SSC (Metric) level Mathematics
Credit Hours	:	03 + 00
Minimum Contact Hours	:	40
Assessment	:	written examination;
Effective	:	2008 and onward

Aims : To give the basic knowledge of Statistics and prepare the students not majoring in Statistics

Objectives: After completion of this course the student should be able to:

- Understand the use of the essential tools of basic Statistics;
- Apply the concepts and the techniques in their respective disciplines.

Unit 1. What is Statistics?

Definition of Statistics, Population, Sample, Descriptive and Inferential Statistics, Observations, Data, Discrete and continuous variables, Errors of measurement, Significant digits, Rounding of a Number, Collection of primary and secondary data, Sources, Editing of Data, Exercises.

Unit 2. Presentation of Data

Introduction, basic principles of classification and Tabulation, Constructing of a frequency distribution, Relative and Cumulative frequency distribution, Diagrams, Graphs and their Construction, Bar charts, Pie chart, Histogram, Frequency polygon and Frequency curve, Cumulative Frequency Polygon or Ogive, Historigram, Ogive for Discrete Variable, Types of frequency curves, Exercises.

Unit 3. Measures of Central Tendency

Introduction, Different types of Averages, Quantiles, The Mode, Empirical Relation between Mean, Median and Mode, Relative Merits and Demerits of various Averages. Properties of Good Average, Box and Whisker Plot, Stem and Leaf Display, definition of outliers and their detection, Exercises

Unit 4. Measures of Dispersion

Introduction, Absolute and relative measures, Range, Quartile Deviation, The Mean Deviation, The Variance and standard deviation,

Change of origin and scale, Interpretation of the standard Deviation, Coefficient of variation, Properties of variance and standard Deviation, Standardized variables, Moments and Moments ratios, Exercises.

Unit 5. Probability and Probability Distributions

Discrete and continuous distributions: Binomial, Poisson and Normal Distribution. Exercises

Unit 6. Sampling and Sampling Distributions

Introduction, sample design and sampling frame, bias, sampling and non-sampling errors, sampling with and without replacement, probability and non-probability sampling, Sampling distributions for single mean and proportion, Difference of means and proportions, Exercises.

Unit 7. Hypothesis Testing

Introduction, Statistical problem, null and alternative hypothesis, Type-I and Type-II errors, level of significance, Test statistics, acceptance and rejection regions, general procedure for testing of hypothesis, Exercises.

Unit 8. Testing of Hypothesis- Single Population

Introduction, testing of hypothesis and confidence interval about the population mean and proportion for small and large samples, Exercises

Unit 9. Testing of Hypotheses-Two or more Populations

Introduction, Testing of hypothesis and confidence intervals about the difference of population means and proportions for small and large samples, Analysis of Variance and ANOVA Table, Exercises

Unit 10. Testing of Hypothesis-Independece of Attributes

Introduction, Contingency Tables, Testing of hypothesis about the Independence of attributes, Exercises

Unit 11. Regression and Correlation

Introduction, cause and effect relationships, examples, simple linear regression, estimation of parameters and their interpretation, Correlation, Coefficient of linear correlation, its estimation, and interpretation of r and R^2. Multiple regression and interpretation of its parameters, Examples

Recommended Books:

1 Walpole, R. E. 1982. “Introduction to Statistics”, 3rd Ed., Macmillan Publishing Co., Inc. New York.

2 Muhammad, F. 2005. “Statistical Methods and Data Analysis”, Kitab Markaz, Bhawana Bazar Faisalabad.

MS/M.Phil. STATISTICS (2 Years programme)

MS/M.Phil. Statistics will contain a total of 36 Credit Hours out of which 24(12+12) will comprise course work in the first two semesters (1st year of study) and final two semesters will be for thesis / research equivalent to 12 Credit Hours.

Detail of Credit Hours is as follows:-

Semester	No. of Subjects	Credit Hours	Total Credit Hours
1st	4	3	12
2nd	4	3	12
3rd + 4th	Thesis / Research Work		6
Total Credit Hours for MS Statistics			**30**

Courses:

STAT-701 Advanced Probability Theory
STAT-702 Linear Models
STAT-703 Advanced Statistical Inference
STAT-704 Advanced Regression Analysis
STAT-705 Advanced Design of Experiments
STAT-706 Advanced Multivariate Analysis
STAT-707 Regression Models for Count Data
STAT-708 Time Series Analysis and Forecasting
STAT-709 Advanced Categorical Data Analysis
STAT-710 Logical Reasoning and Research Methods
STAT-711 Survey Sampling
STAT-712 Longitudinal Data Analysis
STAT-713 Survival Data Analysis
STAT-714 Applied Stochastic Models
STAT-715 Spatial Data Analysis
STAT-716: Advanced Distribution Theory
STAT-717 Inference in Stochastic Processes
STAT-718 Advanced Bayesian Inference
STAT-719 Optimization Techniques
STAT-720 Ecological Statistics

STAT-721 Statistical Methods for Clinical Trials
STAT-722 Bayesian Inference
STAT-723 Financial Stochastic Models
STAT-724 Statistical Genetics
STAT-725 Generalized Linear Models
STAT-726 Meta Analysis
STAT-727 Decision Trees
STAT-728 Generalized Linear Mixed Models
STAT-729 Advanced Operations Research
STAT-730 Multilevel Modeling
STAT-731 Environmental Statistics
STAT-732 Advanced Statistical Methods in Quality Control
STAT-733 Applied Smoothing Techniques
STAT-734 Convergence in Probability
STAT-735 Meta Analysis
STAT-736 Structural Equation Models
STAT-737 Causal Inference

Note: All courses can be offered depending upon the availability of faculty.

Detail of Courses

STAT- 701: Advanced Probability Theory

Course Objectives:

- To impart a conceptual knowledge of random variables and probability theory.
- To use the advanced probability theory in mathematical statistics.
- To strengthen the theoretical basis for future research.

Learning Outcomes:

- Understanding the advanced concepts of probability theory.
- Learning and developing the mathematical theories.
- Acquiring the solution oriented research skills using mathematical statistics.

Course Contents:

An overview of measure theory, fields and sigma-fields, limits of sequences of subsets, sigma-field generated by a class of subsets, Borel fields, Probability, measure on a sigma-fields, probability space, continuity of a probability measure. Real and vector-valued random variables, distribution functions, discrete and continuous random variables, decomposition of c.d.f, transformation of random variables, independence of r.v.s, Borel zero-one law, Expectation of a real r.v. and of a complex-valued r.v. Linear properties of expectations, characteristic functions, their simple properties, uniqueness

theorem. Convergence of a sequence of r.v.s., convergence in distribution, convergence in probability, Kolmogorov strong law of large numbers (without proof), monotone convergence theorem and dominated convergence theorem, continuity theorem for characteristic functions. Lindeberg's CLT and its particular cases.

Recommended Books:

1. Billingsley, P. (1995). *Probability and Measure*, John Wiley & Sons, New York, USA.
2. Casella, G. and Berger, R.L. (2008). *Statistical Inference,* Cengage Learning, New York, USA.
3. Feller, W. (2008). *Introduction to Probability and its Applications*, John Wiley & Sons, New York, USA.
4. Kolmogorov, A.N. (2013). *Foundations of the Theory of Probability,* Martino Fine Books*,* New York, USA.
5. Stuart, A. and Ord, K. (2010) *Kendall's Advanced Theory of Statistics, Distribution Theory*, John Wiley & Sons, New York, USA.

STAT- 702: Linear Models

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

Learning Outcomes:

- 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: Linear least squares problem, 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 the Linear Model.* Duxbury Press.
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.
6. Rencher, A.C. (2000). *Linear Models in Statistics.* Wiley.

STAT- 703: Advanced Statistical Inference

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- 704: Advanced Regression Analysis

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- 705: Advanced Design of Experiments

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:

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-706: Advanced Multivariate Analysis

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- 707: Regression Models for Count Data

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- 708: Time Series Analysis and Forecasting

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.
   Kirchgassner, G. and Jurgen Wolters (2007), Introduction to Modern Time Series Analysis, Springer Berlin Heidelberg New York
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- 709: Advanced Categorical Data Analysis

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-710: Logical Reasoning and Research Methods

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.

Learning Outcomes:

- 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, 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, formulation of research problems and its significance, preparation of research design, components of research design, questionnaires and interviews, preparation of research report, Multidimensional scaling.

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.

STAT- 711: Survey Sampling

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 Errors, Observational Errors, Incomplete Sampling, Non-response, Effects 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 Scale, Guttman Scale, Sematic Differential, A Survey of Super population Models. Randomization theory results for SRS Model for SRS, and model for ratio and Regression Estimation. Model for Stratified Sampling, Cluster Sampling, Models for unequal Probability Sampling, Complex Surveys, Variance Estimations in Complex Surveys, Categorical Data Analysis in Complex Surveys, Regression Analysis for Complex Survey, Effects of Survey Design on Regression Analysis, Effects 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: Longitudinal Data Analysis

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-713: Survival Data Analysis

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, Exponential Distribution, Weibull Distribution Lognormal Distribution, the Extended Generalized Gamma Distribution, the Log-Logistic Distribution, Gompertz Distribution, 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; Log-Likelihood Ratio Test for Comparing Two Survival Distributions, Comparison of Two Exponential Distributions, Comparison of Two Weibull Distributions, Comparison of Two 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

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- 714: Applied Stochastic Models

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 process, discrete and continuous time Markov chains, birth-death process, immigration and emigration process, immigration-death processes, 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- 715: Spatial Data Analysis

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 aerial unit configuration, spatial auto-correlation and spectral analysis, models of spatial auto-correlation, 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- 716: Advanced Distribution Theory

Course Objectives:

- To explore the basic concept of classical and modern probability distributions
- To provide knowledge of extension of classical probability distributions
- To gain sound knowledge of the mathematical characteristics of probability distributions

Learning Outcomes:

- Have a strong basis in probability and distribution theory
- A sound knowledge and understanding of the behavior of random variables
- Be able to apply different probability distributions

Course Contents:

Probability measures, expectations, conditioning, functions of random variables, generating functions, characteristic functions, convergence of random sequences, law of large numbers, central limit theory, discrete distributions, continuous distributions, mixing of probability distributions, transformation of discrete and continuous variable, special sampling distributions: central and non–central case.

Recommended books:

1. Hogg, R.V. and Craig, A.T. (2014). *Introduction to Mathematical Statistics. 7th* ed. Prentice Hall, New Jersey.

2. Johnson, N.L., Kotz, S. and Balakrishnan, N. (1994). *Continuous Univariate Distribution.* Vol-1 & 2, 2nd ed. John Wiley and Sons.
3. Mood, A.M. Graybill, F.A. and Boss, D.C. (1997). *Introduction to the Theory of Statistics.* 3rd ed. McGraw-Hill, New York.
4. Rohatgi, V. K. and Saleh, A. K. MD. (2015). *An Introduction to Probability and Statistics.* 3rd ed. John Wiley and Sons, New York.
5. Stuart, A and Ord, J.K. (2003). *Kendall's Advanced Theory of Statistics.* Vol. I, 6th ed. Charles Griffen and Co. Ltd., London.

STAT- 717: Inference in Stochastic Processes

Course Objectives:

- This course aims to provide an understanding of inferences in Markov processes and the ability to analyze certain aspects of this process.
- It provides concept of martingale, strong law of large numbers and Central Limit Theorem for martingales.
- Furthermore, it also provides the asymptotic distribution theory about the processes in context.

Learning Outcomes:

- To draw the inferences about Markov processes and the ability to analyze certain aspects of this process.
- To analysis of parametric Pure Jump processes and other processes.
- Devise solutions with probability models for Poisson processes, discrete, continuous time Markov chains and other processes. It will be also helpful in current research in this field.

Course Contents:

Inference in Markov chains, estimation of transition probabilities, testing for order of a Markov chain, estimation of functions of transition probabilities, parametric models and their goodness of fit. Markov sequences, estimation of parameters based on likelihood and conditional least squares, auto-regressive series, Statement of martingale, strong law of large numbers and Central Limit Theorem for martingales, CAN property of the MLE from a general sequence of dependent random variables, Fisher information, Applications to Markov chains and sequences. Likelihood of Poisson and other Pure Jump Markov processes from first principles, CAN property of MLE's, testing for a Poisson process, non-homogeneous processes, Analysis of parametric Pure Jump processes, Birth-Death-Immigration processes, testing goodness of fit of such models diffusion processes and their likelihood, properties of estimators, Branching processes, inconsistency of MLE and moment estimators, Properties of estimators on the nonextinction path, asymptotic distribution theory. Elements of semi-parametric and non-parametric analysis, theory and applications of optimal estimating functions, estimation of transition and stationary density, intensity function of a counting process.

Recommended Books:

1. Basawa, I.V. and Rao , B.L.S.P. (1980). *Statistical Inference for Stochastic Processes*, Academic Press, New York, USA.
2. Billingsley, P. (1962). *Statistical Inference for Markov chains*, Chicago University Press, Chicago, USA.
3. Guttorp, P. (1991). *Statistical Inference for Branching Processes*, John Wiley & Sons, New York, USA.
4. Guttorp, P. (1995). *Stochastic Modelling for Scientific Data*, Springer, New York, USA.
5. Prakasa Rao, B.L.S. and Bhat, B. R. (1996). *Stochastic Processes and Statistical Inference*, New Age International Publisher, Chennai, India.

STAT-718: Advanced Bayesian Inference

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:

Bayesian Inference and its ingredients, different types of Prior and their uses, Conditional independence, Exchangeability, Inference based on one parameter model (Binomial and Poisson), Inference based on two parameter model (Normal), Posterior predictive distributions, Introduction to Monte Carlo method, Posterior approximation with Gibbs Sampler (GS), The Metropolis (MA) Algorithm, Bayesian Regression, Generalized linear models, Non-conjugate priors and implementation of the MA, Hierarchical models.

Recommended Books:

1. Carlin, B.P. and Louis, T.A. (2008). *Bayesian Methods for Data Analysis*,. Chapman & Hall/CRC, New York, USA.
2. Congdon, P. (2006). *Bayesian Statistical Modelling*, John Wiley & Sons, New York, USA.
3. Gelman, A., Carlin, J.B., Stern, H.S. and Rubin, D.B. (2014). *Bayesian Data Analysis*, Chapman & Hall/CRC, New York, USA.

4. Hoff, P.D. (2009). *A First Course in Bayesian Statistical Methods*, Springer, New York, USA.

STAT- 719: Optimization Techniques

Course Objectives:

- To understand the advance knowledge of operations research
- To identify and develop operation research model and its applications
- To understand the simulation techniques

Learning Outcomes:

- To develop the understanding of the decision analysis, and knowledge about the game theory
- To identify the best path for the network of optimization problem
- To develop the mathematical tools for getting optimum solutions

Course Contents:

Definition of Operation Research (OR), nature and scope of operation research, Objectives of OR, Major phases of OR study, development of OR models and its application in various scenarios of business.

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 advance linear programming model (LPM), properties of advance LPM, formulation of advance LPM, simplex method fundamentals, revised simplex method, boundary variables algorithms, duality, parametric linear programing. Introduction to non-linear programming, constraint and unconstrained algorithms.

Integer linear programing, its application and algorithms, Deterministic dynamic programming, recursive nature of computation in DP, forward and backward recursion.

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.

Networking models, its definition and scope, various algorithm for the networking, Maximum flow models, CPM and PERT, Deterministic inventory (DI) models. Development of DI models and its applications. Probabilistic inventory models and its application.

Introduction to Decision analysis and games , classification of decisions, steps in decision theory approach, decision making under uncertainity, decision making under risk, criterion of optimism, criterion of pessimism, Hurwicz criterion, regret criterion, Decision making with and without experimentation, Baye's decision rule, decision trees. Game theory and optimal solution of two person zero sum games, mixed strategy games.

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 operation research study.

Recommended Books:

1. Gupta, P. K. & Hira D. S. (2015) , *Operations Research.* 5th edition, S. Chand Publications. New Delhi.
2. Hiller F. S. & Liberman, G. J. (2001). *Introduction to Operations Research.* 7th ed., McGraw-Hill.
3. Murthy, P.R. (2007). *Operations Research.* 2nd edition, New age international publishers, New Delhi.
4. Taha, H. A. (2007). *Operations Research: An Introduction.* 8th ed., Pearson Prentice Hall, Upper Sadle River, NJ.

STAT-720: Ecological Statistics

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

STAT 721: Statistical Methods for Clinical Trials

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. Friedman L.M., Furberg C. and DeMets D.L. (2010). *Fundamentals of Clinical Trials.* Springer Verlag, New York.
2. Rosenberg, W.F. and Lachin, J.M. (2002). *Randomization in Clinical Trials: Theory and Practice*. Wiley, New York.
3. C. Jennison and B. W. Turnbull (1999). *Group Sequential Methods with Applications to Clinical Trials.* CRC Press.
4. Chow S.C. and Liu J.P. (2003). *Design and Analysis of Clinical Trials: Concepts and Methodologies*. 2nd edition, John Wiley & Sons.
5. E. Marubeni and M. G. Valsecchi (1994). *Analyzing Survival Data from Clinical Trials and Observational Studies.* Wiley & Sons.

STAT-722: Bayesian Inference

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:

Bayesian Inference and its ingredients, different types of Prior and their uses, Conditional independence, Exchangeability, Inference based on one parameter model (Binomial and Poisson), Inference based on two parameter model (Normal), Posterior predictive distributions, Introduction to Monte Carlo method, Posterior approximation with Gibbs Sampler (GS), The Metropolis (MA) Algorithm, Bayesian Regression, Generalized linear models, Non-conjugate priors and implementation of the MA, Hierarchical models.

Recommended books:

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

STAT- 723: Financial Stochastic Models

Course Objective:

- Understand the properties of financial time series at level and its returns.
- Modeling and forecasting of financial return series. Modeling volatility using contemporary techniques of GARCH type models.
- Calculate Value at Risk, understand Trading Strategies, modeling long run relationships in Finance. Understanding of simulation techniques.

Learning Outcomes:

- Have understanding of financial time series data especially financial return series data. Use event-study methodology in applied research
- Test the standard asset pricing models. Investigate market interdependence (in the mean and variance equations)
- Estimate non-linear models
- Forecast financial data using high-level econometric techniques and measure their effectiveness. Explore the spillover effect in financial return series

Course Contents:

Understanding Financial Data, Asset Returns and their Empirical Properties, Linear Regression Tests of Financial Models, Efficient portfolio and Capital Asset Pricing Model, Multifactor Pricing Models, Intertemporal Equilibrium and Stochastic Discount Models, Simulation Methods for Financial Derivatives, Linear Time Series Methods, An Introduction to Volatility, Risk and Volatility Models, Value at Risk, Univariate GARCH type Models, Multivariate GARCH type models, Forecast and Management of Market Risks, Modeling Long-Run Relationships in Finance, Trading Strategies and High Frequency Data Review.

Recommended Books:

1. Brooks, Chris (2008), *Introductory Econometrics for Finance*, 2nd Ed., Cambridge University Press.
2. Campbell, J. Y., A. W. Lo, and A. C. MacKinlay (1997),*The Econometrics of Financial Markets*, Princeton University Press.
3. Cuthbertson. K., and Nitzsched. D, (2005), *Quantitative Financial Economics*, John Wiley & Sons.
4. Tsay, R. S. (2005). *Analysis of financial time series* (Vol. 543). John Wiley & Sons.

STAT-724: Statistical Genetics

Course Objectives:

- The importance of Statistical genetics within the Life and Behavioral 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 analyze data from human/animal and plant genetics. A background in statistical methods and applied multivariate analysis at the undergraduate level is assumed with no any necessity of background in genetics.
- To introduce the Microarray Gene Expression data matrix and its evaluation relationship with applied multivariate techniques

Learning Outcomes:

- 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. Laird, N. M., & Lange, C. (2010). *The fundamentals of modern statistical genetics*. Springer Science & Business Media.
2. Wu, R., Ma, C., & Casella, G. (2007). *Statistical genetics of quantitative traits: linkage, maps and QTL*. 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. Reilly, C. (2009). *Statistics in human genetics and molecular biology*. CRC Press.
5. McLachlan, G., Do, K. A., & Ambroise, C. (2005). *Analyzing microarray gene expression data* (Vol. 422). John Wiley & Sons.
6. Gibson, G. (2009). Statistical Genetics: Gene Mapping Through Linkage and Association. *Genes, Brain and Behavior*, *8*(1), 127-128.

STAT- 725: Generalized Linear Models

Course Objectives:

- To understand the concept of generalized linear model
- To improve the student's ability to apply the theory in exploratory data analysis and further in statistical modelling
- To learn multi-category response models in the field of generalized linear models

Learning Outcomes:

- Understand and be proficient at theoretical developments in the analysis of linear models, including linear hypothesis testing, analysis of variance, etc
- Apply the results from linear model theory in advanced topics, such as Over-dispersed models, Quasi-likelihood models, generalized and multivariate analysis
- Read statistical papers involving linear model theory on their own

Course Contents:

Review of Linear Models for Normal Data: Linear regression, ANOVA, Analysis of covariance. Extending the General Linear Model: The exponential class, Linear and non-linear link functions. Theory of Estimation and Model Fitting: Likelihood functions and maximum likelihood, Iteratively reweighted least squares. Theory of Statistical Inference: The deviance function, Analysis of deviance, Likelihood ratio tests, Wald tests, Confidence regions. Classical normal-based models, Logistic and other binary regression, Log-linear models for count data, Gamma regression models. Over-dispersed models, Quasi-likelihood models, generalized estimating equations, Multi-category response models.

Recommended Books:

1. Dobson, A. J., and Barnett, A. (2008). *An introduction to generalized linear models.* CRC press.
2. Fahrmeir, L., and Tutz, G. (2013). *Multivariate statistical modelling based on generalized linear models.* Springer Science & Business Media.
3. Hardin, J. W., Hilbe, J. M., and Hilbe, J. (2007). *Generalized linear models and extensions.* Stata press.

4. McCulloch, C., and Searle, S. (2001). *Generalized, linear and mixed models.* Wiley, New York.
5. Peter McCullagh and John A Nelder. (1989). *Generalized Linear Models*, Second Edition, Chapman and Hall.

STAT- 726 : Meta Analysis

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:

What is meta analysis, why we need 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- 727: Decision Trees

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, Twoing 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,* John Willey & Sons, New York, USA.
2. Bramer, M. (2007). *Principles of Data Mining*. Springer, New York, USA.
3. Breiman, L., Friedman, J.H., Olshen, R.A. & Stone, C.J. (1984). *Classification and Regression Trees*. Wadsworth International Group, Belmont, CA, USA.
4. Efron, B. & Tibshirani, R. J. (1993). *An Introduction to the Bootstrap*. Chapman & Hall, New York, USA.
5. Ripley, B. D. (1996). *Pattern Recognition and Neural Networks*. Cambridge, New York, USA.
6. Tan, P., Steinbach, M. & Kumar, V. (2006). *Introduction to Data Mining*, Addison Wesley, New York, USA.

Stat-728: Generalized Linear Mixed Models

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 create responsibility and awareness in user and consumer of GLMM models.

- To teach standard linear models, GLMMs and the models beyond GLMMs.
- To educate the use of statistical software to model GLMMs.

Learning Outcomes:

- 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 & 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- 729: Advanced Operations Research

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 analyzing 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 uncertainity, decision making under risk, criterion of optimism, criterion of pessimism, Hurwicz criterion, regret criterion, Decision making with and without experimentation, Baye's 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. 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 – 730: Multilevel Modeling (3 Cr. 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- 731: Environmental Statistics

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). Env Stats, 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- 732: Advanced Statistical Methods in Quality Control

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. Feigenbaum, A.V. (1986). *Total Quality Control*, McGraw-Hill, New York, USA.

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- 733: Applied Smoothing Techniques

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. Fan, J. and Gijbels, I. (2013). *Local Polynomial Modeling and its Applications*, CRC Press, New York USA.

2. Härdle, W. (2011). *Applied Nonparametric Regression*, Cambridge University Press, New York, USA.
3. Schimek, M.G. (2012). *Smoothing and Regression: Approaches, Computation and Application*, Johan Wiley & Sons, New York, USA.
4. Scott, D.W. (2015). *Multivariate Density estimation: Theory, practice and visualization*, Johan Wiley & Sons, New York, USA.
5. Simonoff, J. S. (1998). *Smoothing Methods in Statistics*, Springer, New York, USA.
6. Wand, M. P. and Jones, M. C. (1995). *Kernel Smoothing*, Chapman and Hall, New York, USA.

STAT-734: Convergence in Probability

Course Objectives:

- This course aims to provide an understanding of weak convergence in metric spaces measure, integral and related spaces.
- Explains the theorems and their properties that will be helpful research in the field of probability.
- Furthermore, it gives the solution of Brownian bridge problems.

Learning Outcomes:

- Demonstrate knowledge of and properties of convergence in metric spaces measures.
- Understand the basic principles of Construction of wiener measure, Donsker's theorem and Brownian bridge problems.
- Able to do research in the field of mathematical statistics in order to meet the current research at international level.

Course Contents:

Concept of convergence, Weak convergence in metric spaces, measure and integral. Tightness with some examples. Properties of weak convergence. The portmanteau theorem and Other criteria, the mapping theorem of product spaces. Convergence in distributions, convergence in probability. Prohovov's theorem, relative compactness. Tightness with the proof. The space C: Weak convergence and tightness in C. wiener measure. Construction of wiener measure. Donsker's theorem proof and applications. The Brownian bridge problems, maximal inequalities. Maxmia of partial sums. A more general inequality. A further inequality. Problems.

Recommended Books:

1. Billingsley, P. (2012). *Probability and Measures*, John Wiley & Sons, New York, USA.
2. Billingsley, P. (1987). *Weak Convergence of Measures: Applications in Probability*, SIAM, Philadelphia, USA.
3. Hall, P. , Birnbaum, Z.W., Lukacs, E. and Heyle, C.C. (1980). *Martingale Limit Theory and Its Application*, Academic Press, New York, USA.

4. Protter, E.P. (2005). *Stochastic Integration and Differential Equations*, Springer, New York, USA.
5. Vaart, A.V.D. and Wellner, J. (2000). *Weak Convergence and Empirical Processes*, Springer, New York, USA.

STAT- 736: Structural Equation Models

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. Byrne, B. M. (2006). Structural equation modeling with EQS and EQS/Windows: Basic concepts, applications, and programming. Thousand Oaks, CA: Sage Publications.
3. Byrne, B. M. (2016). Structural equation modeling with AMOS: Basic concepts, applications, and programming. Routledge - Taylor and Francis Group, New York.
4. Hoyle, R.H. (2012). Handbook of Structural Equation Modeling. The Guilford Press, ISBN 978-1-60623-077-0.
5. Kline, R.B. (2015). Principles and Practice of Structural Equation Modeling, 4th ed. New York: The Guilford Press.
6. Schumacker, R. E., & Lomax, R. G. (2012). *A beginner's guide to structural equation modeling*. Routledge.

STAT-737: Causal Inference

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

Ph.D. (STATISTICS)

Admission requirement:

For admission into the PhD minimum CGPA 3.0 (out of 4.0 in the Semester System) or First Division (in the Annual System) in M.Phil/M.S/Equivalent is required.

Course Work:

Course work of **18 credit hours** preferably in the first year is required to be completed and followed by a comprehensive examination for granting candidacy as PhD researcher.

Note: Any course(s) from the elective list given before M.Phil/MS curriculum (or any other Ph.D. level course being offered in the respective university), that has not been taken by the student at M.Phil./MS level, can be taken to complete the requirement of **18 credit hours**.

Foreign Expert Evaluation:

The Ph.D. Dissertation must be evaluated by at least two Ph.D. experts from technologically/academically advanced foreign countries in addition to local Committee members.

Open Defense:

An open defense of Dissertation is essential part of PhD Program after positive evaluation.

Research Paper:

Acceptance/publication of at least one research paper in an HEC approved “X” category journal is a requirement for the award of Ph.D. degree (“Y” in case of Social Sciences only).

Plagiarism Test:

The Plagiarism Test must be conducted on the Dissertation before its submission to the two foreign experts.

Copy of PhD Dissertation to HEC:

A copy of Ph.D. Dissertation (both hard and soft) must be submitted to HEC for record in Ph.D. Country Directory and for attestation of the PhD degree by the HEC in future.