Anekant Education Society's

Tuljaram Chaturchand College

of Arts, Science and Commerce, Baramati

(Empowered Autonomous)

M.Sc. Degree Program in Statistics-
(Faculty of Science & Technology)

CBCS Syllabus
M.Sc. Part – II (Statistics) Semester – IV
For Department of Statistics

Tuljaram Chaturchand College of Arts, Science and Commerce, Baramati

Choice Based Credit System Syllabus (2023 Pattern)
(As Per NEP 2020)

To be implemented from Academic Year 2024-2025

Program Outcomes for M.Sc.

1. Comprehensive Knowledge and Understanding:

Postgraduates will possess a profound understanding of their field, encompassing foundational theories, methodologies, and key concepts within a multidisciplinary context.

2. Practical, Professional, and Procedural Knowledge:

Postgraduates will acquire practical skills and expertise necessary for professional tasks, including industry standards, regulations, and ethical considerations, with effective application in real-world scenarios.

3. Entrepreneurial Mindset, Innovation, and Business Understanding:

Postgraduates will cultivate an entrepreneurial mindset, identify opportunities, foster innovation, and understand business principles, market dynamics, and risk management strategies.

4. Specialized Skills, Critical Thinking, and Problem-Solving:

Postgraduates will demonstrate proficiency in technical skills, analytical abilities, effective communication, and leadership, adapting and innovating in response to changing circumstances.

5. Research, Analytical Reasoning, and Ethical Conduct:

Postgraduates will exhibit observational and inquiry skills, formulate research questions, utilize appropriate methodologies for data analysis, and adhere to research ethics while effectively reporting findings.

6. Communication, Collaboration, and Leadership:

Postgraduates will effectively communicate complex information, collaborate in diverse teams, demonstrate leadership qualities, and facilitate cooperative efforts toward common goals.

7. Digital Proficiency and Technological Skills:

Postgraduates will demonstrate proficiency in using ICT, accessing information sources, analyzing data using appropriate software, and adapting to technological advancements.

8. Multicultural Competence, Inclusive Spirit, and Empathy:

Postgraduates will engage effectively in multicultural settings, respect diverse perspectives, lead diverse teams, and demonstrate empathy and understanding of others' perspectives and emotions.

9. Value Inculcation, Environmental Awareness, and Ethical Practices:

Postgraduates will embrace ethical and moral values, practice responsible citizenship, recognize and address ethical issues, and promote sustainability and environmental conservation.

10. Autonomy, Responsibility, and Accountability:

Postgraduates will apply knowledge and skills independently, manage projects effectively, and demonstrate responsibility and accountability in work and learning contexts, contributing to societal well-being.

Anekant Education Society's

Tuljaram Chaturchand College, Baramati

(Autonomous)

Board of Studies (BoS) in Statistics

From 2022-23 to 2024-25

Sr. No.	Name	Designation
1.	Prof. Dr. Vikas C. Kakade	Chairman
2.	Prin. Dr. Avinash S. Jagtap	Member
3.	Dr. Neeta K. Dhane	Member
4.	Dr. Vaishali V. Patil	Member
5.	Mrs. Sarita D. Wadkar	Member (Ad hoc)
6.	Dr. Chandrashekhar P. Swami	Member
7.	Dr. Priti S. Malusare	Member (Ad hoc)
8.	Dr. Nilambari A. Jagtap	Member (Ad hoc)
9.	Miss. Kalyani C. Kale	Member (Ad hoc)
10.	Dr. Pooja S. Gaikwad	Member (Ad hoc)
11.	Dr. Akanksha S. Kashikar	Vice-Chancellor Nominee
12.	Prin. Dr. Rajendra G. Gurao	Expert from other University
13.	Dr. Rohan Koshti	Expert from other University
14.	Mr. Saurabh Kadam	Industry Expert
15.	Dr. Jaya L. Limbore	Meritorious Alumni
16.	Dr. Trupti Arekar	Invitee Member
17.	Miss. Priya N. Rakate	Invitee Member
18.	Ms. Shital B. Choudhar	Invitee Member
19.	Ms. Tejashri D. Kawade	Invitee Member
20.	Miss. Rupali S. Kale	Invitee Member
21.	Miss. Ankita S. Yadav	Invitee Member

22.	Miss. Birnale Sneha Sanjay (M. Sc. Part- II)	Student Representative
23.	Miss. Prabhune Utkarsha Shrinivas (M. Sc. Part- II)	Student Representative
24.	Miss. Chavan Vaishnavi Ajit (TYBSc)	Student Representative
25.	Miss. Gawade Vaishnavi Tukaram (TYBSc)	Student Representative

Credit Distribution Structure for M.Sc. Part-I (Statistics)

Level	Semester	Major		Research Methodology (RM)	OJT/FP	RP	Cum. Cr.	Degree
		Mandatory	Electives					
6.0	Sem-I	STA-501-MJM: Linear Algebra (Credit 04)	STA -511-MJE(A): Mathematical Analysis STA-511-MJE(B): Calculus and Statistical Computing (Credit 04)	STA -521-RM: Research Methodology (Credit 04)	--	--	**20**	PG Diploma (after 3 Year Degree)
		STA -502-MJM: Probability Distributions (Credit 04)						
		STA -503-MJM: Statistics Practical – I (Credit 02)						
		STA -504-MJM: Statistics Practical –II (Credit 02)						
	Sem-II	STA -551-MJM: Multivariate Analysis (Credit 04)	STA -561-MJE (A): Probability Theory STA-561-MJE(B): Stochastic Processes (Credit 04)	--	STA-581-OJT/FP: On Job Training/ Field Project	--	**20**	
		STA -552-MJM: Regression Analysis (Credit 04)						
		STA -553-MJM: Statistics Practical – III (Credit 02)						
		STA -554-MJM: Statistics Practical – IV (Credit 02)						

Credit Distribution Structure for M.Sc. Part-II (Statistics)

Level	Semester	Major		Research Methodology (RM)	OJT /FP	RP	Cum. Cr.	Degree
		Mandatory	Electives					
6.5	Sem-III	STA-601-MJM: Parametric Inference (Credit 04)	STA -611-MJE(A): Data Mining (Credit 02)	--	--	STA-621-RP: Research Project (Credit 04)	**20**	PG Diploma (after 3 Year Degree)
		STA -602-MJM: Design and Analysis of Experiments (Credit 04)	STA-611-MJE(B): Design and Analysis of Clinical Trials (Credit 02)					
		STA -503-MJM: Statistics Practical – V (Credit 02)	STA -612-MJE(A): Machine Learning: Techniques and Applications (Credit 02)					
		STA -504-MJM: Statistics Practical – VI (Credit 02)	STA-612-MJE(B): Practical based on Clinical Trials (Credit 02)					
	Sem-IV	STA -651-MJM: Asymptotic Inference (Credit 04)	STA -661-MJE (A): Survival Analysis (Credit 02)	--	--	STA-621-RP: Research Project (Credit 06)	**20**	
		STA-652-MJM: Time Series Analysis (Credit 04)	STA-661-MJE(B): Actuarial Statistics (Credit 02)					
		STA -653-MJM: Statistics Practical – VII (Credit 02)	STA -662-MJE (A): Practical Based on Statistical Process Control (Credit 02)					
			STA -662-MJE (A): Practical Based on Optimization Techniques (Credit 02)					

Course Structure for M.Sc. Part-I (Statistics) (2023 Pattern)

Sem	Course Type	Course Code	Course Title	Theory/ Practical	No. of Credits
I	Major (Mandatory)	STA-501-MJM	Linear Algebra	Theory	04
	Major (Mandatory)	STA -502-MJM	Probability Distributions	Theory	04
	Major (Mandatory)	STA -503-MJM	Statistics Practical – I	Practical	02
	Major (Mandatory)	STA -504-MJM	Statistics Practical – II	Practical	02
	Major (Elective)	STA-511-MJE (A)	Mathematical Analysis	Theory	04
		STA-511-MJE(B)	Calculus and Statistical Computing	Theory	
	Research Methodology (RM)	STA -521-RM	Research Methodology	Theory	04
	Total Credits Semester I				**20**
II	Major (Mandatory)	STA-551-MJM	Multivariate Analysis	Theory	04
	Major (Mandatory)	STA-552-MJM	Regression Analysis	Theory	04
	Major (Mandatory)	STA-553-MJM	Statistics Practical – III	Practical	02
	Major (Mandatory)	STA-554-MJM	Statistics Practical – IV	Practical	02
	Major (Elective)	STA-561-MJE (A)	Probability Theory	Theory	04
		STA-561-MJE (B)	Stochastic Processes	Theory	
	On Job Training (OJT)/Field Project (FP)	STA-581-OJT/FP	On Job Training Field Project	Training/Project	04
	Total Credits Semester-II				**20**
Cumulative Credits Semester I and II					**40**

Course Structure for M.Sc. Part-II (Statistics) (2023 Pattern)

Sem	Course Type	Course Code	Course Title	Theory/ Practical	No. of Credits
III	Major (Mandatory)	STA-601-MJM	Parametric Inference	Theory	04
	Major (Mandatory)	STA -602-MJM	Design and Analysis of Experiments	Theory	04
	Major (Mandatory)	STA -603-MJM	Statistics Practical – V	Practical	02
	Major (Mandatory)	STA -604-MJM	Statistics Practical – VI	Practical	02
	Major (Elective)	STA-611-MJE (A)	Data Mining	Theory	02
		STA-611-MJE(B)	Design and Analysis of Clinical Trials	Theory	
		STA-612-MJE (A)	Machine Learning: Techniques and Applications	Practical	02
		STA-612-MJE(B)	Practical Based on Clinical Trials	Practical	
	RP	STA -621-RP	Research Project	Project	04
				Total Credits Semester III	**20**
IV	Major (Mandatory)	STA-651-MJM	Asymptotic Inference	Theory	04
	Major (Mandatory)	STA-652-MJM	Time Series Analysis	Theory	04
	Major (Mandatory)	STA-653-MJM	Statistics Practical – VII	Practical	02
	Major (Elective)	STA-661-MJE (A)	Survival Analysis	Theory	02
		STA-661-MJE (B)	Actuarial Statistics	Theory	
		STA-662-MJE (A)	Practical Based on Statistical Process Control	Practical	02
		STA-662-MJE (B)	Practical Based on Optimization Techniques	Practical	
	RP	STA-681-RP	Research Project	Project	06
				Total Credits Semester-IV	**20**
				Cumulative Credits Semester III and IV	**40**

Course Structure for M.Sc. Part-II (Statistics)

(2023 Pattern)

Name of the Programme	: M.Sc. Statistics
Program Code	**:** PSST
Class	**:** M.Sc. Part – II
Semester	**:** IV
Course Type	**:** Major Mandatory Theory
Course Name	**:** Asymptotic Inference
Course Code	**:** STA-651-MJM
No. of Credits	**:** 4 credits
No. of Teaching Hours	**:** 60

Course Objectives:

The main objective of this course is to

1. learn and understand asymptotic behavior of the estimators.
2. find and verify the consistent estimator and consistency and asymptotic normality (CAN) estimator.
3. choosing between consistent estimators.
4. learn various methods of finding consistent estimator, CAN estimator, asymptotic relative efficiency (ARE) of consistent estimator.
5. understand the concept of Likelihood Ratio Test (LRT) and derive it.
6. learn the Cramèr family and apply Cramèr-Huzurbazar theorem to derive CAN estimator based on MLE
7. understand and derive large sample test and asymptotic confidence interval.

Course Outcomes:

By the end of the course, students will be able to:

CO1. understand concept of Consistent estimator, CAN estimator.

CO2. obtain consistent estimator and their asymptotic distributions.

CO3. choose the ARE estimator among given various consistent estimators.

CO4. obtain asymptotic distributions of moment estimators, percentile estimators.

CO5. determine maximum likelihood estimator and its asymptotic distributions

CO6. derive Likelihood Ratio Test (LRT), large sample test, Wald's test, and Score test.

CO7. compute asymptotic confidence interval..

Topics and Learning Points

Unit – 1 (18 L)

Consistency: real and vector parameters, invariance of consistency under continuous transformation, Consistent estimators by method of moments and method of percentiles, choosing between consistent estimators, Minimum sample sizes required to attain given level of accuracy, consistency and asymptotic normality (CAN): real and vector parameters, invariance of CAN under differentiable transformations (delta method), generation of CAN estimators using central limit theorem, CAN property of estimators obtained by moments and percentiles, examples of consistent but not asymptotically normal estimators, asymptotic relative efficiency (ARE) of consistent estimator.

Unit – 2 (18 L)

Maximum likelihood estimation, MLE in exponential family, Cramèr family, Cramèr-Huzurbazar theorem, asymptotic properties of maximum likelihood estimators, Solution of likelihood equations, Method of scoring, Newton-Raphson and other iterative procedures, MLE in case of restricted parameter space, super-efficient estimators, extension to vector–valued parameters, inconsistent MLE, special cases such as exponential class of densities and multinomial distribution, Multinomial with cell probabilities depending on a parameter.

Unit – 3 (15 L)

The Likelihood Ratio Test (LRT), asymptotic distribution of log likelihood ratio, Bartlett Correction, Wald Test, Rao’s score test, Likelihood Ratio Test for Multinomials, variance stabilizing transformation and large sample tests.

Unit – 4 (9 L)

Asymptotic confidence intervals: construction and examples, applications to categorical data analysis.

References:

1. Kale B. K. and Muralidharan K. (2015) Parametric Inference: An Introduction, Alpha Science International Ltd.
2. Gupta Anirban Das (2008), Asymptotic Theory of Statistics and Probability, Springer, New York.
3. Dudewicz E. J. and Mishra S. N. (1988) Modern Mathematical Statistics, John Wiley and Sons.
4. Casella G. and Berger R. L. (2001). Statistical Inference, 2nd edition, Duxbury press.
5. Lehmann, E.L. (1986). Testing Statistical Hypotheses (Student Edition).
6. Rohatgi V.K. and Ehsanes Saleh A. K. MD. (2003). An Introduction to Probability and Statistics, (Wiley Eastern, 2nd Ed.).
7. Fergusson T.S. (1996), A course in Large Sample Theory, Chapman and Hall.
8. Deshmukh Shailaja, Kulkarni Madhuri (2021), Asymptotic Statistical Inference: A Basic Course Using R, Springer

COs POs Mapping

Course Outcomes	Programme Outcomes (POs)									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	-	-	-	-	-	-	-	-	-
CO2	-	3	-	-	-	2	-	-	-	-
CO3	3	-	-	-	2	-	-	-	-	2
CO4	-	-	-	-	-	-	-	-	-	-
CO5	-	-	-	3	-	-	-	-	2	-
CO6	-	3	-	-	-	-	-	2	-	-
CO7	-	-	-	-	-	-	-	-	-	-

Weight: 1 - Partially related 2 - Moderately Related 3 - Strongly related

PO1. Comprehensive Knowledge and Understanding:

CO1: Demonstrate a comprehensive understanding of the theoretical foundations of parametric inference, including probability distributions, likelihood functions, estimation, and hypothesis testing.

Weightage: 3 (Strongly Related)

Justification: This CO directly aligns with the goal of acquiring comprehensive knowledge and understanding of theoretical foundations in parametric inference, covering various aspects such as probability distributions, likelihood functions, estimation, and hypothesis testing.

CO4: Apply the factorization theorem to determine sufficient statistics and construct minimal sufficient statistics for given probability distributions, especially within the exponential family and Pitman family.

Weightage: 3 (Strongly Related)

Justification: Understanding and applying the factorization theorem and constructing sufficient statistics are fundamental components of parametric inference. This directly contributes to a comprehensive understanding of the subject matter.

PO2. Practical, Professional, and Procedural Knowledge:

CO2: Construct confidence intervals for unknown parameters in parametric models and interpret their meaning in the context of statistical inference. Develop proficiency in estimating unknown parameters in parametric models.

Weightage: 3 (Strongly Related)

Justification: This CO emphasizes practical skills related to constructing confidence intervals and estimating unknown parameters, which are essential for applying statistical inference techniques in professional settings.

CO6: Estimation and testing procedures to deal with real-life problems.

Weightage: 3 (Strongly Related)

Justification: Dealing with real-life problems requires practical knowledge and procedural skills in estimation and testing procedures, directly aligning with the practical, professional, and procedural knowledge objectives.

PO3. Entrepreneurial Mindset, Innovation, and Business Understanding:

No direct alignment identified.

PO4. Specialized Skills, Critical Thinking, and Problem-Solving:

CO5: Understand UMP tests for one-sided alternatives within the Exponential class of densities and extensions to distributions having Monotone Likelihood Ratio property.

Weightage: 3 (Strongly Related)

Justification: Understanding UMP tests and extensions for different distributions demonstrates specialized skills, critical thinking, and problem-solving abilities, which are crucial for addressing complex statistical problems.

PO5. Research, Analytical Reasoning, and Ethical Conduct:

CO3: Continuously engage in lifelong learning and professional development in the field of parametric inference, staying updated on recent advancements and applying new methodologies to address emerging challenges in data analysis and statistical inference.

Weightage: 2 (Moderately Related)

Justification: Engaging in lifelong learning and professional development reflects a commitment to ethical conduct and research integrity, essential aspects of PO5.

PO6. Communication, Collaboration, and Leadership:

CO2: Construct confidence intervals for unknown parameters in parametric models and interpret their meaning in the context of statistical inference. Develop proficiency in estimating unknown parameters in parametric models.

Weightage: 2 (Moderately Related)

Justification: While not directly related to communication, collaboration, or leadership, this CO involves interpreting and communicating statistical results effectively, which is a form of communication skill. Additionally, collaborating with peers or supervisors in the process of constructing confidence intervals can foster teamwork and collaboration.

PO7. Digital Proficiency and Technological Skills:

No direct alignment identified.

PO8. Multicultural Competence, Inclusive Spirit, and Empathy:

CO6: Estimation and testing procedures to deal with real-life problems.

Weightage: 2 (Moderately Related)

Justification: Employing estimation and testing procedures in various contexts requires sensitivity to different cultural backgrounds and perspectives, indirectly contributing to multicultural competence and fostering an inclusive spirit.

PO9. Value Inculcation, Environmental Awareness, and Ethical Practices:

CO5: Understand UMP tests for one-sided alternatives within the Exponential class of densities and extensions to distributions having Monotone Likelihood Ratio property.

Weightage: 2 (Moderately Related)

Justification: Ethical practices are often implicit in statistical analysis, such as ensuring fairness and transparency in testing procedures. Understanding these tests and their applications contributes to upholding ethical standards in statistical practice.

PO10. Autonomy, Responsibility, and Accountability:

CO3: Continuously engage in lifelong learning and professional development in the field of parametric inference, staying updated on recent advancements and applying new methodologies to address emerging challenges in data analysis and statistical inference.

Weightage: 2 (Moderately Related)

Justification: While not directly addressing autonomy, responsibility, and accountability, this CO promotes a sense of professional responsibility and autonomy in staying updated with advancements in the field and applying them effectively, albeit to a moderate extent.

CBCS Syllabus as per NEP 2020 for M.Sc. Part-II Statistics (2023 Pattern)

Name of the Programme	**:** M.Sc. Statistics
Program Code	**:** PSST
Class	**:** M.Sc. Part – II
Semester	**:** IV
Course Type	**:** Major Mandatory Theory
Course Name	**:** Time Series Analysis
Course Code	**:** STA-652-MJM
No. of Credits	**:** 04
No. of Teaching Hours	**:** 60

Course Objectives:

1. The main objective of this course is that students should understand various time series models, estimation of its parameters and be able to make predictions.
2. To learn the concepts like Auto-covariance, auto-correlation function and vector auto regression.
3. Combine AR and MA processes to create and analyze AutoRegressive Moving Average (ARMA) models.
4. Understand the concepts of causality and invertibility in time series models.
5. Understand and apply Seasonal ARIMA (SARIMA) models for seasonal time Series forecasting.
6. Explore the innovation algorithm and its applications in time series analysis.
7. Understand the Box-Jenkins methodology and its application in developing time series forecasting models.
8. Assess the effectiveness of different time series models in capturing the underlying patterns and making accurate forecasts.

Course Outcomes:

By the end of the course, students will be able to:

CO1. Apply various time series models to real-world datasets and estimate the parameters to make accurate predictions.

CO2. Analyze and interpret the significance of Auto-covariance and Auto-correlation functions in understanding time series dependencies, and implement vector auto-regression models.

CO3. Combine AR and MA processes effectively to create AutoRegressive Moving Average (ARMA) models and analyze their performance in data analysis.

CO4. Evaluate the concepts of causality and invertibility in time series models and apply them to improve model validity.

CO5. Implement Seasonal ARIMA (SARIMA) models to forecast seasonal patterns in time series data, demonstrating proficiency in seasonal time series analysis.

CO6. Apply the innovation algorithm in time series analysis and explore its effectiveness in solving practical problems.

CO7. Develop time series forecasting models using the Box-Jenkins methodology, showcasing the ability to apply this technique to real-world problems.

CO8. Critically assess and compare different time series models, evaluating their effectiveness in capturing underlying patterns and making accurate forecasts.

Topics and Learning Points

Unit 1: (15L)

Exploratory time Series analysis, Time Series as a discrete parameter stochastic process, tests for trend and seasonality, moving average smoothing, exponential smoothing, double (Holt exponential smoothing), Triple (Holt -Winters exponential smoothing), adaptive smoothing definition and its application. Auto covariance and autocorrelation functions and their properties, Portmanteau tests for noise sequences..

Unit 2: (15L)

Stationary process: General linear process, stationary process and strict stationary process, moving average (MA), Auto Regressive (AR) and autoregressive moving average (ARMA). Concept of causality, invertibility, Computation of π-weights and ψ-weights. computation of ACVF and ACF. Partial auto covariance function. Periodogram and correlogram analysis.

Unit 3: (15L)

Non-stationary: Unit root, non-stationary unit root test, Integrated ARMA (ARIMA) model, Analysis of seasonal models: Parsimonious models for seasonal time series, SARIMA models, forecasting, identification, estimation and diagnosis methods for seasonal time series. Yule-Walker estimation. Estimation of ARIMA models parameters, Maximum likelihood method for estimation. Durbin-Levison algorithm, innovation algorithm, Box- Jenkins model (Without proof).

Unit 4: (15L)

Graphical method for choosing AR and MA lags, FPE, AIC, BIC, residual analysis, conditional heteroscedastic models, volatility models, ARCH and GARCH properties, examples,estimation and forecasting. Introduction to Multivariate Time series model, VAR models, vector ARMA models.

References:

1) Brockwell, P.J. and Davis, R. A. Introduction to Time Series Analysis, Springer.
2) Chatfield, C. (2001). Time Series Forecasting, Chapmann & hall, London.
3) Fuller, W. A. (1996). Introduction to Statistical Time Series, 2nd Ed. John Wiley.
4) Hamilton N. Y. (1994). Time Series Analysis. Princeton University press. Princeton.
5) Kendall, Sir Maurice and Ord, J. K. (1990). Time Series (Third Edition), Edward Arnold.

Programme Outcomes and Course Outcomes Mapping:

Programme Outcomes and Course Outcomes Mapping:

Course Outcomes	Programme Outcomes (POs)									
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	3	3	1	3	2	2	2	1	1	2
CO2	3	3	1	3	2	2	2	1	1	2
CO3	3	3	1	3	2	2	2	1	1	2
CO4	3	3	1	3	2	2	2	1	1	2
CO5	3	3	1	3	2	2	2	1	1	2
CO6	2	3	1	2	2	2	2	1	1	2
CO7	3	3	1	3	2	2	2	1	1	2
CO8	3	3	1	3	2	2	2	1	1	2

Weight: 1 - Partially related 2 - Moderately Related 3 - Strongly related

Justification

PO1: Comprehensive Knowledge and Understanding

CO1: Applying time series models and estimating parameters requires a profound understanding of foundational theories and methodologies in time series analysis. **(3)**
CO2: Analyzing auto-covariance and auto-correlation functions involves deep knowledge of time series dependencies and vector auto-regression models. **(3)**
CO3: Combining AR and MA processes to create ARMA models requires comprehensive knowledge of time series models. **(3)**
CO4: Evaluating causality and invertibility concepts requires a thorough understanding of time series models. **(3)**

CO5: Implementing Seasonal ARIMA models involves a comprehensive grasp of seasonal time series analysis. **(3)**
CO6: Applying the innovation algorithm involves understanding advanced time series techniques. **(2)**
CO7: Developing forecasting models using Box-Jenkins methodology requires in-depth knowledge of this approach. **(3)**
CO8: Critically assessing and comparing different time series models involves understanding various models' underlying principles. **(3)**

PO2: Practical, Professional, and Procedural Knowledge

CO1: Applying time series models to real-world datasets involves practical skills and industry-standard procedures. **(3)**
CO2: Analyzing and implementing vector auto-regression models requires practical and professional knowledge in time series analysis. **(3)**
CO3: Creating ARMA models and analyzing their performance involves practical application and procedural knowledge. **(3)**
CO4: Evaluating causality and invertibility involves practical application to improve model validity. **(3)**
CO5: Implementing SARIMA models for forecasting seasonal patterns involves practical skills in time series analysis. **(3)**
CO6: Applying the innovation algorithm requires practical knowledge and problem-solving skills. **(3)**
CO7: Developing forecasting models using Box-Jenkins methodology involves practical application of this technique. **(3)**
CO8: Comparing different models to evaluate effectiveness involves practical application and procedural analysis. **(3)**

PO3: Entrepreneurial Mindset, Innovation, and Business Understanding

CO1: Applying time series models to real-world datasets can demonstrate an innovative approach but does not strongly relate to an entrepreneurial mindset. **(2)**
CO2: Analyzing auto-covariance and implementing models has limited direct relevance to entrepreneurial skills. **(1)**
CO3: Combining AR and MA processes involves technical skills rather than business understanding. **(1)**
CO4: Evaluating model validity involves technical rather than entrepreneurial skills. **(1)**
CO5: Implementing SARIMA models could be applied to business forecasting but is not strongly related to entrepreneurship. **(2)**
CO6: The innovation algorithm reflects some level of innovation but not directly related to an entrepreneurial mindset. **(2)**
CO7: Developing forecasting models using established methodologies can contribute to business understanding but does not strongly reflect entrepreneurial skills. **(2)**
CO8: Comparing different models involves critical evaluation rather than entrepreneurial skills. **(2)**

PO4: Specialized Skills, Critical Thinking, and Problem-Solving

CO1: Applying time series models involves specialized skills and critical thinking in making accurate predictions. **(3)**
CO2: Analyzing auto-covariance and auto-correlation requires specialized skills and critical reasoning. **(3)**
CO3: Combining AR and MA processes involves specialized technical skills and problem-solving. **(3)**
CO4: Evaluating causality and invertibility requires critical thinking to improve model validity. **(3)**
CO5: Implementing SARIMA models involves problem-solving skills in forecasting seasonal patterns. **(3)**
CO6: Applying the innovation algorithm involves specialized skills and problem-solving in time series analysis. **(2)**
CO7: Developing models using Box-Jenkins methodology requires specialized skills and critical thinking. **(3)**
CO8: Critically assessing and comparing models involves extensive critical thinking and specialized skills. **(3)**

PO5: Research, Analytical Reasoning, and Ethical Conduct

CO1: Applying time series models involves research and analytical reasoning to make accurate predictions. **(2)**
CO2: Analyzing auto-covariance and implementing models requires analytical reasoning and understanding of research principles. **(2)**
CO3: Combining AR and MA processes requires analytical skills and understanding of model performance. **(2)**
CO4: Evaluating causality and invertibility involves analytical reasoning and adherence to methodological principles. **(2)**
CO5: Implementing SARIMA models involves research skills and analytical reasoning for accurate forecasting. **(2)**
CO6: Applying the innovation algorithm requires research and analytical skills for solving practical problems. **(2)**
CO7: Developing forecasting models using Box-Jenkins methodology involves research and analytical reasoning. **(2)**
CO8: Critically assessing different models requires analytical reasoning and comparison techniques. **(2)**

PO6: Communication, Collaboration, and Leadership

CO1: Communicating the results of time series models requires effective communication skills. **(2)**
CO2: Interpreting and communicating the significance of auto-covariance and vector auto-regression results involves communication skills. **(2)**
CO3: Communicating the performance of ARMA models requires effective communication of technical results. **(2)**
CO4: Explaining concepts of causality and invertibility involves clear communication of technical aspects. **(2)**

CO5: Communicating the results of SARIMA models requires effective presentation of seasonal forecasting results. **(2)**
CO6: Applying the innovation algorithm involves communicating its effectiveness in solving problems. **(2)**
CO7: Developing forecasting models using Box-Jenkins methodology requires communicating complex results. **(2)**
CO8: Comparing and assessing different models involves communicating comparative analysis effectively. **(2)**

PO7: Digital Proficiency and Technological Skills

CO1: Applying time series models requires proficiency with statistical software and digital tools. **(3)**
CO2: Analyzing and implementing vector auto-regression models requires technological skills. **(3)**
CO3: Creating ARMA models involves using digital tools for data analysis. **(3)**
CO4: Evaluating time series model concepts involves using digital tools for analysis. **(3)**
CO5: Implementing SARIMA models requires proficiency with statistical software and technological skills. **(3)**
CO6: Applying the innovation algorithm involves using digital tools for time series analysis. **(3)**
CO7: Developing forecasting models using Box-Jenkins methodology involves technological proficiency. **(3)**
CO8: Comparing different models involves using technological tools for analysis. **(3)**

PO8: Multicultural Competence, Inclusive Spirit, and Empathy

CO1: Applying time series models does not directly relate to multicultural competence. **(1)**
CO2: Analyzing time series dependencies has minimal relation to multicultural competence. **(1)**
CO3: Combining AR and MA processes does not directly relate to multicultural competence. **(1)**
CO4: Evaluating model validity involves technical aspects rather than multicultural competence. **(1)**
CO5: Implementing SARIMA models is focused on technical skills rather than multicultural competence. **(1)**
CO6: Applying the innovation algorithm is technically focused and does not relate strongly to multicultural competence. **(1)**
CO7: Developing forecasting models is a technical skill with minimal direct relation to multicultural competence. **(1)**
CO8: Assessing and comparing models involves technical analysis rather than multicultural skills. **(1)**

PO9: Value Inculcation, Environmental Awareness, and Ethical Practices

CO1: Applying time series models requires adherence to ethical practices in data analysis. **(1)**
CO2: Analyzing and implementing models involves ethical considerations in interpretation. **(1)**
CO3: Creating ARMA models requires ethical practices in data handling. **(1)**
CO4: Evaluating model validity involves ensuring ethical practices in analysis. **(1)**
CO5: Implementing SARIMA models requires ethical considerations in forecasting practices. **(1)**
CO6: Applying the innovation algorithm involves ethical considerations in solving problems. **(1)**

CO7: Developing models using Box-Jenkins methodology requires adherence to ethical practices. **(1)**
CO8: Comparing and assessing models involves ethical considerations in evaluating results. **(1)**

PO10: Autonomy, Responsibility, and Accountability

CO1: Applying time series models involves autonomy and responsibility for accurate predictions. **(2)**
CO2: Analyzing and implementing models requires responsibility in handling results. **(2)**
CO3: Combining AR and MA processes involves autonomy in creating and analyzing models. **(2)**
CO4: Evaluating causality and invertibility requires responsibility for ensuring model validity. **(2)**
CO5: Implementing SARIMA models requires responsibility in handling seasonal data. **(2)**
CO6: Applying the innovation algorithm involves responsibility and accountability in solving problems. **(2)**
CO7: Developing forecasting models requires autonomy and responsibility for applying the Box-Jenkins methodology. **(2)**
CO8: Comparing and assessing models involves accountability for evaluating effectiveness. **(2)**

CBCS Syllabus as per NEP 2020 for M.Sc. Part-II Statistics (2023 Pattern)

Name of the Programme	**:** M.Sc. Statistics
Program Code	**:** PSST
Class	**:** M.Sc. Part – II
Semester	**:** IV
Course Type	**:** Major Mandatory Practical
Course Name	**:** Statistics Practical – VII
Course Code	**:** STA-653-MJM
Credit	**:** 2 credits
No. of lectures	**:** 60

Course Objectives:

1. To develop a deep understanding of the theoretical foundations of maximum likelihood estimation (MLE), its asymptotic properties, and the behavior of estimators in both small and large samples.
2. To gain proficiency in applying large sample tests, including LRT, Wald Test, and Rao's Score Test, with a focus on power functions and comparison
3. To acquire the ability to analyze time series data using various smoothing techniques, transformations, and tests for stationarity, causality.
4. To develop skills in selecting and fitting time series models (AR, MA, ARMA, ARIMA, SARIMA) using AIC and BIC, and understand the impact on forecasting accuracy.
5. To perform residual analysis and diagnostic checks to assess the adequacy of fitted time series models, ensuring that model assumptions are met and refining models as necessary.
6. To implement advanced statistical methods, such as the Method of Scoring and Newton-Raphson, for solving likelihood equations and maximizing the likelihood function in complex scenarios.
7. To evaluate model performance, forecast future values, and construct confidence and prediction intervals using Holt-Winters and other exponential smoothing techniques.

Course Outcomes:

By the end of the course, students will be able to:

CO1. Demonstrate a strong understanding of the theoretical principles underlying maximum likelihood estimation (MLE) and its application in various statistical models.

CO2. Apply advanced hypothesis testing methods, including Likelihood Ratio Test (LRT), Wald Test, and Rao's Score Test, and assess the power and efficiency of these tests.

CO3. Analyze and interpret time series data using smoothing techniques, transformations, and tests for stationarity, enabling accurate identification of underlying patterns.

CO4. Select and fit appropriate time series models (AR, MA, ARMA, ARIMA, SARIMA) using criteria like AIC and BIC, and assess their impact on forecasting accuracy.

CO5. Evaluate the performance of fitted time series models, forecast future values, and construct confidence and prediction intervals using techniques like Holt-Winters exponential smoothing.

CO6. Conduct thorough residual and diagnostic analyses to validate time series models, ensuring they meet necessary assumptions and are suitable for prediction.

CO7. Implement iterative methods such as the Method of Scoring and Newton-Raphson for solving likelihood equations, especially in the context of complex or constrained parameter spaces.

CO8. Apply multivariate time series and heteroscedastic models (ARCH, GARCH) to analyze complex datasets, particularly in financial or econometric applications, and understand their implications for volatility and risk assessment.

Topics and Learning Points

Sr. No.	Title of Experiments
1	Verification of consistency and asymptotic normality of the estimators
2	Comparing Consistent estimator, MSE and sample size considerations
3	Asymptotic Confidence Intervals
4	Power functions of large sample test (LR, Wald, Rao)
5	Analysis of three-dimensional contingency tables
6	Plotting Likelihood function, MLE by methods of scoring
7	Smoothing time series using various filters (exponential, MA), Box-Cox transformation, differencing, checking stationarity and normality after transformation.
8	ACF/PACF of series and residual analysis, stationarity, causality and invertibility
9	Order selection in time series: use of ACF/PACF and AIC, BIC, fitting of AR, MA models (conditional least squares or maximum likelihood)

10	Fitting of ARMA, ARIMA and SARIMA models (conditional least squares or maximum likelihood).
11	Forecasting using fitted linear models (recursively), Holt -Winters forecasts construction of forecast intervals
12	Fitting heteroscedastic models: checking for heteroscedasticity from residuals, ARCH, GARCH modelling.
13.	Mini Project (3 Practical)

Programme Outcomes and Course Outcomes Mapping:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	1	3	3	2	2	1	1	2
CO2	3	2	1	3	3	2	2	1	1	2
CO3	3	3	2	3	3	2	3	2	2	2
CO4	3	3	2	3	3	2	3	2	2	2
CO5	3	3	2	3	3	2	3	2	2	2
CO6	3	3	2	3	3	2	3	2	2	2
CO7	3	2	1	3	3	2	3	2	2	2
CO8	3	3	2	3	3	2	3	2	2	2

Weight: 1 - Partially related 2 - Moderately Related 3 - Strongly related

PO1: Comprehensive Knowledge and Understanding

CO1, CO2, CO3, CO4, CO5, CO6, CO7, CO8 (3 - Strongly Related): All COs strongly relate to PO1 as they require a deep understanding of theoretical principles, statistical methods, and model-fitting techniques. These concepts form the foundation of the course and are crucial for comprehensive knowledge in the field.

PO2: Practical, Professional, and Procedural Knowledge

CO3, CO4, CO5, CO6, CO8 (3 - Strongly Related): These COs emphasize the practical application of statistical methods, particularly in time series analysis, model selection, forecasting, and diagnostics. Students develop procedural knowledge through hands-on practice and real-world scenarios.

CO1, CO2, CO7 (2 - Moderately Related): These COs involve the application of theoretical knowledge to solve practical problems, but they are more focused on understanding concepts than on direct professional application.

PO3: Entrepreneurial Mindset, Innovation, and Business Understanding

CO3, CO4, CO5, CO6, CO8 (2 - Moderately Related): These COs moderately relate to PO3, as they involve selecting and applying models that can be used in business contexts, particularly in forecasting and risk assessment. However, the course primarily focuses on technical skills rather than entrepreneurship.

PO4: Specialized Skills, Critical Thinking, and Problem-Solving

CO1, CO2, CO3, CO4, CO5, CO6, CO7, CO8 (3 - Strongly Related): All COs are strongly related to PO4, as they require students to apply specialized statistical techniques, engage in critical thinking, and solve complex problems, particularly in time series analysis and hypothesis testing.

PO5: Research, Analytical Reasoning, and Ethical Conduct

CO1, CO2, CO3, CO4, CO5, CO6, CO7, CO8 (3 - Strongly Related): These COs are strongly related to PO5, as they involve applying research methods, conducting analyses, and ensuring the ethical use of statistical techniques. Students must critically evaluate models and test hypotheses as part of their research.

PO6: Communication, Collaboration, and Leadership

CO1, CO2, CO3, CO4, CO5, CO6, CO7, CO8 (2 - Moderately Related**):** These COs are moderately related to PO6. While the course focuses on technical skills, students are expected to communicate their findings and collaborate on projects, particularly in the context of the mini-project (CO13).

PO7: Digital Proficiency and Technological Skills

CO3, CO4, CO5, CO6, CO7, CO8 (3 - Strongly Related): These COs are strongly related to PO7, as they involve using statistical software, performing data analysis, and implementing advanced models, all of which require a high level of digital proficiency.

CO1, CO2 (2 - Moderately Related): These COs involve understanding and applying statistical methods that require some digital skills, though they are more focused on theoretical concepts.

PO8: Multicultural Competence, Inclusive Spirit, and Empathy

CO1, CO2, CO3, CO4, CO5, CO6, CO7, CO8 (1 - Partially Related): These COs are only partially related to PO8. While the course content itself does not directly address multicultural competence, the collaborative aspects of the course, such as group projects, may touch upon these skills.

PO9: Value Inculcation, Environmental Awareness, and Ethical Practices

CO1, CO2, CO3, CO4, CO5, CO6, CO7, CO8 (2 - Moderately Related): These COs are moderately related to PO9. The ethical use of statistical methods and the responsible handling of data are important aspects of the course, aligning with ethical practices and value inculcation.

PO10: Autonomy, Responsibility, and Accountability

CO1, CO2, CO3, CO4, CO5, CO6, CO7, CO8 (2 - Moderately Related): These COs are moderately related to PO10. Students are expected to independently apply their knowledge, take responsibility for their analyses, and be accountable for their results, particularly in research and project work.

CBCS Syllabus as per NEP 2020 for M.Sc. Part-II Statistics (2023 Pattern)

Name of the Programme	: M.Sc. Statistics
Program Code	: PSST
Class	: M.Sc. Part – II
Semester	: IV
Course Type	: Major Mandatory Elective
Course Name	: Survival Analysis
Course Code	: STA-661-MJE(A)
No. of Credits	: 02
No. of Teaching Hours	: 30

Course Objectives:

1. To understand the fundamental concepts and principles of survival analysis.
2. To develop the ability to analyze time- to- event data using appropriate statistical methods.
3. To learn the mathematical foundations underlying survival distributions and hazard functions
4. To decide the type of censoring and truncation that is the basis for given survival data.
5. To estimate survival functions using parametric and non-parametric methods.
6. To compare survival functions of two or more populations.
7. To use software for survival analysis.

Course Outcomes:

By the end of the course, students will be able to:

After completing this paper, the student will be able to:

CO1. identify applications with time to event outcomes.

CO2. estimate the survival function parametrically using various parametric models from the given survival data

CO3. construct a life table using the actuarial approach.

CO4. construct a life table using the Kaplan-Meier approach.

CO5. perform and interpret the log rank test.

CO6. compute and interpret a hazard ratio.

CO7. learn about censored and understand how to handle these issues in survival analysis.

Topics and Learning Points

Unit – 1 **(12L)**

Meaning of censoring, concepts of time, order and random censoring (left and right), hybrid censoring survival function, density function, hazard function (rate), cumulative hazard rate, mean residual life function, percentile residual life function, Equilibrium distribution function. Exponential distribution and it's no ageing properties: Lack of memory property, constant failure rate, Cauchy-function equation, constant mean residual life function, TTT transform, identity function as a TTT transform, aging classes - IFR, IFRA, NBU, NBUE, DMRL, HNBUE and their duals, and inter relationship among these classes. Bathtub Failure rate.

Unit – 2 (9L)

Life distributions - Exponential Gamma, Weibull, Lognormal, Pareto, linear Failure rate. Likelihood based on parametric inference point estimation, confidence interval .

Estimation of survival function - Actuarial Estimator, Kaplan – Meier Estimator, Empirical survival function.

Unit – 3 (9L)

Test for Exponetiality: Estimable function of degree r, Kernel, symmetric Kernel, U- statistic, variance of U- Statistic, one sample U-Statistic theorem, Hollander and Proschan Test, Test for exponetiality against positive ageing based n sample spacing, Analytical test for exponentiality against NBUE, Deshpande's Test, Two sample U- statistic theorem, Wilcoxon and Mann –Whitney test, Gehan's test, Mantel- Haenzel test, Log rank test, Semi-parametric regression for failure rate-Cox proportional hazards model with one and several covariates.

References:

1. Cox, D.R. and Oakes, D. (1984) Analysis of Survival Data, Chapman and Hall, New York.
2. Deshpande ,J.V, Purohit, S. G.,(2005), Life Time Data :Statistical Models and Methods
3. Elandt - Johnson, R.E., Johnson N.L. (1980) Survival models and Data Analysis, John Wiley and Sons
4. Gross A.J. and Clark, V. A. (1975) Survival Distributions: Reliability Applications in the Biomedical Sciences, John Wiley and Sons.
5. Miller, R.G. (1981) Survival Analysis (Wiley)
6. David G. Kleinbaum and Mitchel Klein, (2020) Survival Analysis A Self-Learning Text, Third Edition, (Springer)

Programme Outcomes and Course Outcomes Mapping:

Course Outcomes	Programme Outcomes (POs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	2	2	1	2	2	1	1	1	1	1
CO2	3	3	1	2	3	1	1	1	1	1
CO3	3	3	1	2	3	1	1	1	1	1
CO4	3	3	1	2	3	1	1	1	1	1
CO5	2	2	1	3	3	1	1	1	1	1
CO6	2	2	1	3	3	1	1	1	1	1
CO7	2	2	1	2	2	1	1	1	1	1

Justification

PO1: Comprehensive Knowledge and Understanding

CO1: Identifying applications with time-to-event outcomes requires understanding fundamental concepts in survival analysis. **(2)**

CO2: Estimating survival functions using parametric models demonstrates deep knowledge of survival analysis methodologies. **(3)**

CO3: Constructing a life table using actuarial approaches requires understanding foundational theories. **(3)**

CO4: Constructing a life table using the Kaplan-Meier approach also involves foundational knowledge but with a specific methodology. **(3)**

CO5: Performing and interpreting the log-rank test requires understanding of statistical methods related to survival analysis. **(2)**

CO6: Computing and interpreting hazard ratios involves understanding of advanced survival analysis concepts. **(2)**

CO7: Learning about censored data involves knowledge of survival analysis principles. **(2)**

PO2: Practical, Professional, and Procedural Knowledge

CO1: Applying time-to-event analysis requires practical knowledge in survival analysis. **(2)**

CO2: Parametric estimation involves practical skills and procedures in survival analysis. **(3)**

CO3: Constructing life tables using actuarial methods is a practical application of professional knowledge. **(3)**

CO4: Constructing life tables using Kaplan-Meier is a practical application relevant to survival analysis. **(3)**

CO5: Performing and interpreting log-rank tests involves practical skills in survival data analysis. **(3)**

CO6: Hazard ratios calculation and interpretation are practical tasks in survival analysis. **(3)**

CO7: Handling censored data is a practical challenge in survival analysis. **(2)**

PO3: Entrepreneurial Mindset, Innovation, and Business Understanding

CO1: Understanding applications of survival outcomes may have indirect links to business understanding. **(1)**

CO2: Parametric modeling does not strongly relate to an entrepreneurial mindset or business understanding. **(1)**

CO3: Constructing life tables is more about technical skill than entrepreneurial mindset. **(1)**

CO4: Kaplan-Meier life tables also focus on technical aspects rather than business understanding. **(1)**

CO5: The log-rank test is a statistical tool rather than an entrepreneurial skill. **(1)**

CO6: Calculating hazard ratios has limited direct relevance to entrepreneurial skills. **(1)**

CO7: Understanding and handling censored data are primarily technical tasks with limited entrepreneurial application. **(1)**

PO4: Specialized Skills, Critical Thinking, and Problem-Solving

CO1: Identifying time-to-event applications involves critical thinking and specialized skills. **(2)**

CO2: Parametric estimation requires specialized skills and problem-solving. **(3)**

CO3: Constructing life tables involves both specialized skills and critical thinking. **(3)**

CO4: Kaplan-Meier life tables also involve critical thinking and specialized skills. **(3)**

CO5: Performing and interpreting the log-rank test involves critical thinking and specialized analysis. **(3)**

CO6: Computing and interpreting hazard ratios require advanced problem-solving skills. **(3)**

CO7: Handling censored data involves problem-solving skills in survival analysis. **(2)**

PO5: Research, Analytical Reasoning, and Ethical Conduct

CO1: Identifying applications involves analytical reasoning but less research. **(2)**

CO2: Estimating survival functions involves significant analytical reasoning and some research skills. **(3)**

CO3: Constructing life tables is related to analytical reasoning and research methodologies. **(3)**

CO4: Kaplan-Meier life tables also involve research skills and analytical reasoning. **(3)**

CO5: Log-rank test performance and interpretation require research and analytical reasoning. **(3)**

CO6: Computing hazard ratios involves analytical reasoning and research skills. **(3)**

CO7: Understanding and handling censored data require research and analytical reasoning. **(2)**

PO6: Communication, Collaboration, and Leadership

CO1: Identifying applications with time-to-event outcomes may require some level of communication but is not highly related. **(1)**

CO2: Communicating results of parametric models requires some communication skills. **(1)**

CO3: Constructing life tables might involve communicating results effectively. **(1)**

CO4: Kaplan-Meier life tables also involve communicating technical results. **(1)**

CO5: Performing and interpreting the log-rank test might require effective communication of findings. **(2)**

CO6: Hazard ratios need to be communicated clearly in reports or presentations. **(2)**

CO7: Handling censored data may involve communication about complex issues in analysis. **(1)**

PO7: Digital Proficiency and Technological Skills

CO1: Identifying applications involves some digital skills but not extensively. **(1)**

CO2: Parametric estimation typically requires proficiency with statistical software. **(3)**

CO3: Constructing life tables often requires using actuarial software or tools. **(3)**

CO4: Kaplan-Meier life tables require digital tools for computation. **(3)**

CO5: Performing log-rank tests involves using statistical software. **(2)**

CO6: Computing hazard ratios requires technological skills for data analysis. **(2)**

CO7: Handling censored data involves using digital tools for survival analysis. **(2)**

PO8: Multicultural Competence, Inclusive Spirit, and Empathy

CO1: Time-to-event outcomes applications have limited relevance to multicultural competence. **(1)**

CO2: Estimating survival functions is less related to multicultural competence. **(1)**

CO3: Constructing life tables has limited direct relevance to multicultural issues. **(1)**

CO4: Kaplan-Meier life tables are primarily technical with limited relevance to multicultural competence. **(1)**

CO5: Performing log-rank tests involves statistical analysis with limited multicultural relevance. **(1)**

CO6: Computing hazard ratios is a technical skill with little direct relevance to multicultural competence. **(1)**

CO7: Understanding censored data has limited connection to multicultural issues. **(1)**

PO9: Value Inculcation, Environmental Awareness, and Ethical Practices

CO1: Applications with time-to-event outcomes involve ethical considerations but not strongly. **(1)**

CO2: Parametric models involve ethical practices related to accurate data interpretation. **(2)**

CO3: Constructing life tables requires ethical consideration of data handling. **(2)**

CO4: Kaplan-Meier tables also involve ethical data handling practices. **(2)**

CO5: Performing and interpreting the log-rank test involves ethical considerations in analysis. **(2)**

CO6: Hazard ratios calculation requires ethical interpretation of results. **(2)**

CO7: Handling censored data involves ethical considerations in analysis. **(2)**

PO10: Autonomy, Responsibility, and Accountability

CO1: Identifying applications with time-to-event outcomes involves some level of responsibility. **(1)**

CO2: Estimating survival functions requires autonomy in applying models and responsibility for results. **(2)**

CO3: Constructing life tables involves significant responsibility and autonomy. **(3)**

CO4: Kaplan-Meier life tables require responsibility and autonomy in application. **(3)**

CO5: Performing and interpreting log-rank tests involves accountability in analysis. **(2)**

CO6: Computing hazard ratios requires responsibility and accountability in interpretation. **(2)**

CO7: Handling censored data involves responsibility for accurate analysis. **(2)**

CBCS Syllabus as per NEP 2020 for M.Sc. Part-II Statistics (2023 Pattern)

Name of the Programme	**:** M.Sc. Statistics
Program Code	**:** PSST
Class	**:** M.Sc. Part – II
Semester	**:** IV
Course Type	**:** Major Elective Theory
Course Name	**:** Actuarial Statistics
Course Code	**:** STA-661-MJE(B)
No. of Credits	**:** 2 credits
No. of Teaching Hours	**:** 30

Course Objectives:

1. To provide a comprehensive understanding of the principles and practices of insurance business in actuarial science.
2. To explain the application of utility theory in insurance, focusing on risk assessment and decision-making under uncertainty.
3. To study and apply various mortality models, including Gompertz' and Makeham's laws in insurance.
4. To introduce the concept of time-until-death random variables and related functions such as the survival function, distribution functions, and force of mortality.
5. To provide a detailed understanding of different types of life insurance products and their actuarial present values.
6. To explore the mathematical and actuarial principles underlying various types of annuity contracts, including discrete, continuous, and life annuities.
7. To introduce students to the principles of premium calculation, the concept of reserves, and the methods for determining net and gross premiums for insurance and annuity products.

Course Outcomes:

By the end of the course, students should be able to:

CO1. identify and analyze consequences of events involving risk and uncertainty.

CO2. calculate survival function, curtate future lifetime, force of mortality.

CO3. calculate various payments from life tables using principle of equivalence, net premiums, prospective and retrospective reserve.

CO4. understand the principles of risk management and how they apply to actuarial practice.

CO5. gain insights into the insurance and financial industries, including current trends, challenges, and opportunities.

CO6. apply actuarial techniques to real-world scenarios and case studies.

CO7. explore ethical considerations and responsibilities in the actuarial profession.

Topics and Learning Points

Unit 1: (6L)

Introduction to Insurance Business, insurance and utility theory, time-until-death random variable, survival function, distribution function, density functions and force of mortality and curtate-future lifetime random variable its probability mass function, deferred probabilities, all these functions in terms of international actuarial notation. Analytical laws of mortality such as Gompertz' law and Makeham's law

Unit 2: (8L)

Principles of compound interest: Nominal and effective rates of interest and force of interest and discount, compound interest, accumulation factor, continuous compounding. Life insurance: Insurance payable at the moment of death and at the end of the year of death, level benefit insurance, whole life insurance, endowment insurance, deferred insurance and varying benefit insurance, recursion equation, Actuarial present value of the benefit. net single premiums.

Unit 3: (10L)

Annuity contracts, annuity certain, discrete annuity, m-thly annuity, deferred annuity, present values and accumulated values of these annuities. Continuous life annuity, discrete life annuity such as whole life annuity, temporary life annuity, n-year certain and life annuity, life annuities with m-thly payments. Present value random variables for these annuity payments, their means and variances, Actuarial present value of the annuity.

Unit 4: (06L)

Loss at issue random variable, various principles to decide net premiums for insurance products and annuity schemes defined in unit II and III, fully continuous premiums and fully discrete premiums, true m-thly payment premiums, extended equivalence principle to decide gross premiums, concept of reserve, prospective and retrospective reserve, fully continuous reserve, fully discrete reserve.

References:

1) Bowers, JR. N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J. (1997). Actuarial Mathematics, 2nd Edn, the Society of Actuaries.
2) Deshmukh S.R. (2009). Actuarial Statistics: An Introduction Using R, Universities Press.
3) Actuarial Mathematics, Society of Actuaries,ltasca,lllinois,U.S.A.2nd Ed.(1997)

4) Spurgeon E.T. (1972); Life Contingencies, Cambridge University Press. Neill, A. Life Contingencies, Heinemann
5) Harriett, E.J. and Dani, L. L.(1999). Principles of Insurance: Life, Health, and Annuities, 2nd Edn., Life Office Management Association.
6) Neill, Alistair (1977). Life Contingencies, The Institute of Actuaries.
7) Palande, P. S., Shah, R. S. and Lunawat, M. L. (2003). Insurance in India - Changing Policies and Emerging Opportunities, Response Books.

Programme Outcomes and Course Outcomes Mapping:

Course Outcomes	Programme Outcomes (POs)									
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	2	2	1	3	3	1	1	1	2	1
CO2	2	3	1	2	3	1	1	1	1	1
CO3	2	3	1	2	3	1	1	1	1	1
CO4	2	3	2	3	2	2	1	1	2	1
CO5	2	2	2	2	2	2	2	2	2	1
CO6	3	3	2	3	3	3	2	1	1	1
CO7	2	2	1	2	2	1	1	1	3	2

Justification

PO1: Comprehensive Knowledge and Understanding

CO1: Understanding consequences of risk events relates to foundational theories and methodologies in actuarial science. **(2)**

CO2: Calculating survival functions and related metrics requires a deep understanding of actuarial concepts. **(2)**

CO3: This involves applying foundational actuarial principles, hence a moderate relationship. **(2)**

CO4: Principles of risk management are fundamental to actuarial practice, showing moderate relevance. **(2)**

CO5: Insights into industry trends require a broad understanding of the field. **(2)**

CO6: Applying actuarial techniques shows a strong grasp of foundational concepts. **(3)**

CO7: Ethical considerations are informed by comprehensive knowledge of the field. **(2)**

PO2: Practical, Professional, and Procedural Knowledge

CO1: Risk analysis requires practical knowledge of actuarial procedures. **(2)**

CO2: Calculation skills are central to professional actuarial practice. **(3)**

CO3: This CO involves practical application of actuarial principles and procedures. **(3)**

CO4: Understanding and applying risk management principles in practice. **(3)**

CO5: Understanding industry trends relates to professional knowledge. **(2)**

CO6: Application of techniques to real scenarios is strongly related to practical knowledge. **(3)**

CO7: Ethical responsibilities are a part of professional conduct. **(2)**

PO3: Entrepreneurial Mindset, Innovation, and Business Understanding

CO1: Risk and uncertainty may relate to business understanding but not strongly. **(1)**

CO2: This CO is less related to entrepreneurial mindset or business understanding. **(1)**

CO3: Similarly, this CO is not strongly related to entrepreneurial aspects. **(1)**

CO4: Risk management principles may include some entrepreneurial elements. **(2)**

CO5: Insights into the insurance and financial industries are relevant to business understanding. **(2)**

CO6: Applying actuarial techniques can be linked to entrepreneurial innovation. **(2)**

CO7: Ethical considerations have indirect relevance to entrepreneurial mindset. **(1)**

PO4: Specialized Skills, Critical Thinking, and Problem-Solving

CO1: Analyzing risk involves critical thinking and problem-solving. **(3)**

CO2: Calculations require specialized skills and problem-solving. **(2)**

CO3: This CO involves solving problems using actuarial methods. **(2)**

CO4: Risk management involves critical thinking and specialized skills. **(3)**

CO5: Insights and industry understanding involve problem-solving and critical thinking. **(2)**

CO6: Applying techniques to scenarios requires specialized skills and critical thinking. **(3)**

CO7: Ethical considerations involve critical thinking and responsible problem-solving. **(2)**

PO5: Research, Analytical Reasoning, and Ethical Conduct

CO1: Analyzing consequences involves analytical reasoning. **(3)**

CO2: Calculations are based on analytical reasoning. **(3)**

CO3: Calculation and application require analytical skills and research-like methods. **(3)**

CO4: Understanding risk management involves analytical and research skills. **(2)**

CO5: Insights into industry trends may require some level of research and analytical reasoning. **(2)**

CO6: Real-world applications involve research and analytical skills. **(3)**

CO7: Ethical considerations are tied to research and analytical reasoning in the actuarial context. **(3)**

PO6: Communication, Collaboration, and Leadership

CO1: Communication may not be directly related, but analyzing risk can involve collaboration. **(1)**

CO2: Calculations are individual tasks with limited direct communication aspects. **(1)**

CO3: Communicating results and collaborating on actuarial tasks can be relevant. **(1)**

CO4: Understanding risk management principles can involve teamwork and communication. **(2)**

CO5: Gaining industry insights involves communication and collaboration. **(2)**

CO6: Real-world applications and case studies may require effective communication and collaboration. **(2)**

CO7: Discussing ethical considerations involves communication and leadership. **(1)**

PO7: Digital Proficiency and Technological Skills

CO1: Risk analysis may involve digital tools but isn't directly tied to digital proficiency. **(1)**

CO2: Calculations often require technological tools, indicating moderate relevance. **(1)**

CO3: Calculating payments involves the use of actuarial software and tools. **(1)**

CO4: Applying risk management may involve digital tools. **(1)**

CO5: Understanding industry trends involves digital proficiency. **(2)**

CO6: Applying actuarial techniques relies on technological skills. **(2)**

CO7: Ethical considerations have limited direct relevance to digital proficiency. **(1)**

PO8: Multicultural Competence, Inclusive Spirit, and Empathy

CO1: Analyzing risk may not directly involve multicultural competence. **(1)**

CO2: Calculations are technical and do not directly relate to multicultural competence. **(1)**

CO3: Application of calculations is less related to multicultural competence. **(1)**

CO4: Understanding risk management principles may involve some multicultural aspects. **(1)**

CO5: Insights into the industry can include aspects of multicultural competence. **(2)**

CO6: Real-world applications might involve diverse perspectives. **(1)**

CO7: Ethical considerations can involve understanding diverse perspectives. **(3)**

PO9: Value Inculcation, Environmental Awareness, and Ethical Practices

CO1: Understanding risk and uncertainty has limited direct relevance to values and environmental awareness. **(2)**

CO2: Calculations themselves do not involve ethical practices. **(1)**

CO3: Calculations for payments might be related to ethical practices, though indirectly. **(1)**

CO4: Principles of risk management often include ethical practices. **(2)**

CO5: Industry insights can include aspects of value inculcation and ethical practices. **(2)**

CO6: Applying techniques ethically involves values and ethical practices. **(2)**

CO7: Exploring ethical considerations is directly related to ethical practices. **(3)**

PO10: Autonomy, Responsibility, and Accountability

CO1: Analyzing consequences involves taking responsibility and accountability. **(1)**

CO2: Performing calculations independently shows responsibility and autonomy. **(1)**

CO3: Similar to CO2, involves responsibility in calculating payments. **(1)**

CO4: Risk management involves responsibility and accountability in practice. **(2)**

CBCS Syllabus as per NEP 2020 for M.Sc. Part-II Statistics (2023 Pattern)

Name of the Programme : M.Sc.
Statistics**Program Code** : PSST
Class : M.Sc. Part – II
Semester : IV
Course Type : Major Elective Practical
Course Name : Practical Based on Statistical Process Control
Course Code : STA-662-MJE(A)
No. of Credits : 2 credits
No. of Teaching Hours : 60

Course Objectives:

1. To learn concepts of SPC, including control charts, process variation, common cause variation, and special cause variation.
2. To understand and implement SPC Techniques: Ensures foundational knowledge and practical skills in SPC, essential for effective process control.
3. To measure and improve process performance against standards.
4. To enhance proficiency in advanced tools, allowing for sophisticated monitoring and process improvement.
5. To provides essential statistical skills for validating process improvements and supporting quality control decisions.
6. To develops analytical skills to understand and leverage control charts for process optimization.
7. To emphasizes the importance of clear communication and reporting in making informed decisions and facilitating process improvements.
8. To ensures that students can apply their knowledge practically, addressing real-world challenges and contributing to process improvements in professional settings.

Course Outcomes:

By the end of the course, students will be able to:

CO1: implement and apply various Statistical Process Control (SPC) techniques, including control charts for both variables and attributes, to real-world data sets.

CO2: evaluate process capability using capability indices (Cp, Cpk) and assess how well processes meet specifications and standards.

CO3: utilize advanced SPC tools, including Cumulative Sum (CUSUM) charts and Exponentially Weighted Moving Average (EWMA) charts, to monitor and improve process performance.

CO4: perform hypothesis testing and calculate confidence intervals to support decision-making related to process improvements and quality control.

CO5: analyze and interpret synthetic and non-parametric control charts to identify patterns, trends, and anomalies in process data.

CO6: communicate SPC findings, results, and recommendations effectively to various stakeholders, using clear and concise reports and presentations.

CO7: apply practical knowledge of SPC to troubleshoot and provide solutions for real-world process issues and quality problems.

Topics and Learning Points

Sr. No.	Title of Experiments
1.	Total Quality Management and Quality System
2.	Variable control chart using R-software.
3.	Attribute control chart using R-software.
4.	S^2 and X-S control chart.
5.	Operating Characteristic (OC) Curve.
6.	Average Run Length (ARL).
7.	Average Run Length and Probability false alarm.
8.	Cumulative Sum Control Chart.
9.	Exponential weighted Control Chart.
10.	Comparison between Shewhart, CUSUM and EWMA control chart.
11.	Process capability analysis for normal data.
12.	Synthetic chart for mean.

13.	Multivariate control chart.
14.	Non parametric control chart - I
15.	Non parametric control chart - II

Programme Outcomes and Course Outcomes Mapping:

Course Outcomes	Programme Outcomes (POs)									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	3	1	3	2	1	1	1	3	3
CO2	3	3	1	3	2	1	1	1	3	3
CO3	3	3	1	3	2	1	1	1	3	3
CO4	3	3	1	3	2	1	1	1	3	3
CO5	3	3	1	3	2	1	1	1	3	3
CO6	3	3	1	3	2	1	1	1	3	3
CO7	3	3	1	3	2	1	1	1	3	3

PO1. Comprehensive Knowledge and Understanding

All COs (Weightage: 3 - Strongly Related)

Justification: Understanding applications of statistical process control directly contributes to buildingdisciplinary knowledge in the field.

PO2. Practical, Professional, and Procedural Knowledge

All COs (Weightage: 3 - Strongly Related)

Justification: All outcomes involve critical thinking and problem-solving skills, fromunderstanding statistical process to applying statistical tools for analysis.

PO3. Specialized Skills and Competencies

All COs (Weightage: 1 - Partially Related)

Justification: The outcomes are more technical and focused on statistical process techniques, with lessdirect relevance to social competence.

PO4. Capacity for Application, Problem-Solving, and Analytical Reasoning

All COs (Weightage: 3 - Strongly Related)

Justification: The outcomes align closely with research-related skills and the development of a scientific temper in the context of statistical process control.

PO5. Learning How to Learn Skills

All COs (Weightage: 2 - Moderately Related)

Justification: Acquiring knowledge of statistical process control involves trans-disciplinary aspects,making this outcome moderately related.

PO6. Digital and Technological Skills

All COs (Weightage: 1 - Partially Related)

Justification: The outcomes contribute more to technical competence in statistical process control, with limited direct connections to personal and professional aspects.

PO7. Effective Citizenship and Ethics

All Cos (Weightage: 1 - Partially Related)

Justification: The content is more technical and less directly related to citizenship and ethics.

PO8. Environment and SustainabilityAll COs

(Weightage: 1 - Partially Related)

Justification: The outcomes are more focused on statistical processes on environmental or sustainability aspects.

PO9. Self-directed and Life-long Learning

All COs (Weightage: 3 - Strongly Related)

Justification: Stochastic processes and actuarial mathematics are dynamic fields, and mastering their principles requires ongoing self-directed learning and adaptation.

PO10. Value Inculcation and Environmental Awareness

All COs (Weightage: 3 - Strongly Related)

Justification: Related through ethical communication practices.

CBCS Syllabus as per NEP 2020 for M.Sc. Part-II Statistics (2023 Pattern)

Name of the Programme	: M.Sc. Statistics
Program Code	: PSST
Class	: M.Sc. Part – II
Semester	: IV
Course Type	: Major Elective Practical
Course Name	: Practical Based on Optimization Techniques
Course Code	: STA-662-MJE(B)
No. of Credits	: 2 credits
No. of Teaching Hours	: 60

Course Objectives:

1. To Understand and apply the Simplex algorithm, solve linear programming problems using artificial variable techniques, including the Two-Phase and Big-M methods.
2. To Gain a deep understanding of duality in Linear Programming Problems (LPP), and apply duality theory to test optimality in various optimization problems such as the transhipment problem.
3. To Learn and implement advanced techniques such as the cutting plane method (Gomory's method) for both all-integer and mixed-integer linear programming problems, as well as the Branch and Bound method.
4. Develop proficiency in nonlinear programming and quadratic programming problems using methods like Wolfe's and Beale's techniques.
5. To Explore the principles of dynamic programming and apply them to deterministic processes, sequential and non-sequential discrete optimization problems
6. To develop inventory models for single-item inventory control, including EOQ models with and without shortages.
7. To Perform sensitivity analysis to assess the impact of changes on feasibility and optimality in optimization problems,

Course Outcomes:

By the end of the course, students will be able to:

CO1. solve linear programming problems using artificial variable techniques .

CO2. apply duality theory to test optimality in various optimization problems such as the transshipment problem.

CO3. learn and implement advanced techniques such as all-integer and mixed-integer linear programming problems.

CO4. develop proficiency in nonlinear programming and quadratic programming problems.

CO5. explore the principles of dynamic programming and apply them to deterministic processes

CO6. develop inventory models for single-item inventory control, including EOQ models with and without shortages.

CO7. perform sensitivity analysis to assess the impact of changes on feasibility and optimality in optimization problems.

Topics and Learning Points

Sr. No.	Title of Experiments
1.	Getting basic feasible solution to given LPP.
2.	Graphical solution to LPP with 2 decision variables.
3.	Solving the primal LP (or dual LP) by using Simplex method.
4.	Solving the primal LP (or dual LP) by using following methods. i) Charne's Big-M method. ii) Dual simplex method.
5.	Getting optimal solution for dual LP (without solving DLP) using optimal solution for primal LP.
6.	Sensitivity Analysis in Linear Programming.
7.	Practical's based on inventory models.
8.	Simulation of various queuing models and verification of their steady state distributions.
9.	Solving Additional Constraints / Fractional Cutting Plane by Gomory's method
10.	Solving Mixed Integer Linear Programming by Gomory's method
11.	Solving dynamic programming: Bellman's Optimality Principle model I,II
12.	Dynamic programming Approach for solving linear programming problem
13.	Solving graphical method for non linear programming
14.	Solving Quadratic programming problem using Kuhn-Tucker conditions
15.	Solving Quadratic programming problem using Wolfes Method

Programme Outcomes and Course Outcomes Mapping:

Course Outcomes	Programme Outcomes (POs)									
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	2	3	1	3	3	2	2	3	3	1
CO2	2	3	1	3	3	2	2	3	3	1
CO3	2	3	2	3	3	2	2	3	3	1
CO4	2	3	2	3	3	2	2	3	3	1
CO5	2	3	2	3	3	2	2	3	3	1
CO6	2	3	1	3	3	2	2	3	3	1
CO7	2	3	2	3	3	2	2	3	3	1

Weight: 1 - Partially related 2 - Moderately Related 3 - Strongly related

Justification:

PO1. Comprehensive Knowledge and Understanding

CO1 (2): Understanding linear programming problems contributes moderately to foundational theories and key concepts in the field of optimization.

CO2 (2): Applying duality theory builds a moderate foundation in core optimization principles.

CO3 (2): Implementing advanced techniques like mixed-integer programming relates moderately to the broad knowledge base in operations research.

CO4 (2): Nonlinear and quadratic programming extends into more advanced optimization theories, contributing to a comprehensive understanding.

CO5 (2): Dynamic programming's application in deterministic processes supports a moderate understanding of broader theories and principles.

CO6 (2): Developing inventory models taps into key principles of optimization, contributing to understanding of inventory theory.

CO7 (2): Sensitivity analysis relates to foundational concepts of optimization, contributing moderately to understanding.

PO2. Practical, Professional, and Procedural Knowledge

CO1 (3): Solving linear programming problems is crucial for practical application in professional optimization tasks.

CO2 (3): Duality theory is essential for testing optimality, a professional skill in optimization and operations research.

CO3 (3): Implementing all-integer and mixed-integer programming is strongly related to practical applications and industry standards.
CO4 (3): Nonlinear programming has practical applications in complex optimization tasks and is relevant for real-world scenarios.

CO5 (3): Dynamic programming principles are used in practical problem-solving in various industries.

CO6 (3): Developing inventory models is directly applicable to industrial and commercial inventory control.

CO7 (3): Sensitivity analysis is crucial for real-world decision-making, assessing how changes affect feasibility and optimality.

PO3. Entrepreneurial Mindset and Knowledge
CO1 (1): Solving linear programming problems partially contributes to an entrepreneurial mindset by fostering analytical thinking.

CO2 (1): Duality theory contributes partially by helping identify efficient solutions, a key entrepreneurial skill.

CO3 (2): Advanced techniques like integer programming support moderate innovation and problem-solving, key entrepreneurial skills.

CO4 (2): Nonlinear programming fosters moderate innovation in complex decision-making, supporting entrepreneurial efforts.

CO5 (2): Dynamic programming supports moderate entrepreneurial mindset by solving complex, process-driven problems.

CO6 (1): Developing inventory models slightly relates to entrepreneurship by optimizing resources and managing risk.

CO7 (2): Sensitivity analysis helps entrepreneurs assess risks and adapt strategies, supporting innovation and decision-making.

PO4. Specialized Skills and Competencies
CO1 (3): Solving linear programming problems directly develops specialized skills in optimization.

CO2 (3): Duality theory application strengthens problem-solving skills in optimization.

CO3 (3): Advanced programming techniques enhance specialized technical skills in operations research.

CO4 (3): Nonlinear programming develops specific technical competencies in optimization.

CO5 (3): Dynamic programming enhances problem-solving skills, critical in specialized fields.

CO6 (3): Inventory model development builds specialized skills in logistics and supply chain management.

CO7 (3): Sensitivity analysis builds strong analytical skills, crucial for optimization specialists.

PO5. Capacity for Application, Problem-Solving, and Analytical Reasoning.

CO1 (3): Solving linear programming problems enhances the ability to apply concepts and solve problems.

CO2 (3): Duality theory application strengthens analytical reasoning and problem-solving capacity.

CO3 (3): Implementing advanced techniques in programming fosters strong analytical and problem-solving skills.

CO4 (3): Nonlinear programming challenges require advanced problem-solving and critical thinking.

CO5 (3): Dynamic programming application strengthens analytical reasoning in process-driven problems.

CO6 (3): Inventory models require problem-solving and critical analysis, enhancing analytical reasoning.

CO7 (3): Sensitivity analysis demands strong analytical skills to evaluate the impact of changes on optimization.

PO6. Communication Skills and Collaboration

CO1 (2): Solving linear programming problems involves communicating results and collaborating on problem-solving tasks.

CO2 (2): Duality theory application requires effective communication to interpret and share results.

CO3 (2): Implementing advanced techniques often requires collaboration with teams, contributing moderately to communication skills.

CO4 (2): Nonlinear programming requires clear communication of complex problem solutions.

CO5 (2): Dynamic programming application necessitates teamwork and effective communication of process-driven outcomes.

CO6 (2): Inventory models require communication of results and collaboration on implementation.

CO7 (2): Sensitivity analysis results must be effectively communicated, especially in decision-making contexts.

PO7. Research-related Skills

CO1 (2): Solving linear programming problems requires moderate research into methodologies and techniques.

CO2 (2): Duality theory involves inquiry and the testing of optimality, fostering research-related skills.

CO3 (2): Implementing advanced programming techniques requires researching methods and their applications.

CO4 (2): Nonlinear programming involves research into specialized methods, contributing moderately to research skills.

CO5 (2): Dynamic programming requires research into its principles and applications in different fields.

CO6 (2): Developing inventory models often involves research into best practices and methodologies.

CO7 (2): Sensitivity analysis fosters research-related skills by assessing the impact of various factors on outcomes.

PO8. Learning How to Learn Skills

CO1 (3): Solving linear programming problems fosters learning new methods and approaches to optimization.

CO2 (3): Duality theory application involves continuous learning and adapting to new challenges.

CO3 (3): Implementing advanced techniques encourages self-directed learning in specialized optimization areas.

CO4 (3): Nonlinear programming requires continuous learning and adapting to complex problems.

CO5 (3): Dynamic programming involves learning to apply its principles to new and varied scenarios.

CO6 (3): Developing inventory models fosters ongoing learning about best practices and methodologies.

CO7 (3): Sensitivity analysis encourages continuous learning by assessing various impacts on solutions.

PO9. Digital and Technological Skills

CO1 (3): Solving linear programming problems requires strong proficiency in using optimization software and tools.

CO2 (3): Duality theory application often involves digital tools for testing and analysis.

CO3 (3): Advanced techniques in programming require using specialized software, fostering digital skills.

CO4 (3): Nonlinear programming involves the use of advanced software tools for problem-solving.

CO5 (3): Dynamic programming application requires technological proficiency in process modeling tools.

CO6 (3): Developing inventory models often involves using specialized software, enhancing digital skills.

CO7 (3): Sensitivity analysis requires proficiency in digital tools for data analysis and optimization.

PO10. Multicultural Competence, Inclusive Spirit, and Empathy

CO1 (1): Solving linear programming problems contributes slightly by fostering collaborative problem-solving in diverse teams.

CO2 (1): Duality theory application involves working in teams, contributing slightly to multicultural competence.

CO3 (1): Implementing advanced techniques can involve collaboration with diverse groups, fostering inclusion.

CO4 (1): Nonlinear programming application in diverse settings enhances empathy and understanding of different perspectives.

CO5 (1): Dynamic programming fosters inclusiveness through teamwork and collaborative problem-solving.

CO6 (1): Developing inventory models in multicultural contexts can enhance understanding of diverse business practices.

CO7 (1): Sensitivity analysis fosters empathy by understanding the impacts of decisions on different stakeholders.

CBCS Syllabus as per NEP 2020 for M.Sc. Part-II Statistics (2023 Pattern)

Name of the Programme	: M.Sc. Statistics
Program Code	: PSST
Class	: M.Sc. Part – II
Semester	: IV
Course Type	: Major Mandatory Practical
Course Name	: Research Project
Course Code	: STA-681-RP
Credit	: 6 credits
No. of lectures	: 180

Course Objectives:

1. To equip students with the ability to design and conduct research in their field of study.
2. To enhance critical thinking and analytical skills through the collection, analysis, and interpretation of data.
3. To enable students to apply theoretical concepts and methodologies to real-world research problems.
4. To develop student’s' skills in academic writing, ensuring they can effectively communicate their research findings.
5. To develop an understanding of ethical considerations in research, including data integrity, privacy, and responsible reporting.
6. To enhance student’s abilities to present and defend their research findings in a professional setting.
7. To provide an opportunity for students to work collaboratively on research projects, developing teamwork and project management skills.

Course Outcomes:

By the end of the course, students will be able to:

CO1 design and execute a research project, from beginning to completion.

CO2 acquire advanced skills in data collection, utilizing both primary and secondary sources effectively.

CO3 proficient in analyzing data using appropriate methodologies and tools, drawing meaningful conclusions from their findings.

CO4 critically evaluate existing literature, identifying gaps and positioning their research within the broader academic context.

CO5 produce a well-structured research report, presenting their findings clearly and coherently, with appropriate academic referencing.

CO6 confidently present and defend their research findings before an academic audience, demonstrating mastery of their topic.

CO7 apply ethical principles throughout the research process, ensuring integrity and respect for participants and data.

Guidelines for the Research Project:

In NEP 2020 (2023 Pattern) we are offering to PG (Second Year -Fourth Semester) students **Research Project (RP)** for **Six (6)** credits i.e. **150 Marks**. The total time allocation for the student to carry out Research Project is **180 hours**. The actual field work should be carried out aftercollege hours or on holidays or during summer vacation.

Guidelines for Research Project:

Research-Based Learning: Students will participate in research-based projects under the supervision of a faculty member. The project should focus on a specific area of interest within the student's discipline.

Time Requirement: A minimum of 30 hours of learning per credit is required in a semester. Thus, for 6 credits, students must engage in at least 180 hours of research activity.

Project Topic Assignment: Each student or group of students (2 or 3 students per group; up to 5 students per group for large projects in commerce or social sciences) will be assigned a research topic by a faculty member acting as the guide.

The topic should be relevant, researchable, and contribute to the academic field.

Literature Review and Research Design:

Students will conduct an extensive literature review to understand the current state of research in their chosen topic.

They will develop a research design, including objectives, hypothesis (if applicable), methodology, and tools for data collection.

Data Collection: Students should collect primary and/or secondary data related to their research topic. The collection methods may include surveys, experiments, interviews, observations, or analysis of existing data sets.

Students should aim for comprehensive data collection to ensure robust analysis.

Data Analysis: Students will analyze the collected data using appropriate statistical or qualitative methods.

The analysis should be thorough, and students are encouraged to use software tools where applicable (e.g., SPSS, R, Python).

Research Report Writing:

Students will compile their findings into a research report following a standard academic format.

The report should include an introduction, literature review, methodology, analysis, results, discussion, conclusion, and references.

The typed report should have a minimum of 80 pages, with font size 12 and line spacing of 1.5.

Submission of Research Report:

Two copies of the final research report, signed by the guide, must be submitted to the department.

The report will be evaluated based on content quality, depth of research, and adherence to academic standards.

Oral Presentation:

An oral presentation of the research project will be arranged in the department. Students will present their research findings to faculty members and peers. Evaluation will be conducted by two internal examiners appointed by the Head of the Department (HoD). No external examiner will be appointed.

Evaluation:

The total research project work, from topic selection to the oral presentation, will be evaluated for 6 credits (150 Marks).

The marks will be allocated based on the different stages of the research project, as detailed below.

Completion Requirement:

This research project is a compulsory component of the syllabus.

Passing the Research Project is mandatory for the student to complete their degree program.

Typical Time and marks allocation for the different stages of the Research Project is:

Step of Project	Individual Student's Work in Hours	Marks
Topic Selection / Literature Review	20	15
Research Design / Proposal Writing	30	20
Data Collection	60	40
Data Analysis	30	30
Report Writing	30	25
Oral Presentation		20
Total	**180**	**150**

Programme Outcomes and Course Outcomes Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	3	3	2	2	1	1	3
CO2	2	3	1	1	2	1	3	3	1	1
CO3	3	3	1	3	3	1	1	3	1	1
CO4	3	1	2	3	3	1	1	1	1	1
CO5	2	1	1	1	3	2	1	1	1	1
CO6	1	1	1	1	2	3	1	1	1	2
CO7	1	2	1	1	3	1	1	1	3	1

Mapping Justification:

PO1: Comprehensive Knowledge and Understanding

CO1 (3): Independently designing and executing a research project requires a profound understanding of foundational theories, methodologies, and concepts.

CO4 (3): Critically evaluating literature involves a deep understanding of existing knowledge and identifying gaps.

CO5 (2): Producing a well-structured research report necessitates comprehensive knowledge of academic writing standards and methodologies.

PO2: Practical, Professional, and Procedural Knowledge

CO2 (3): Acquiring advanced skills in data collection involves practical knowledge and adherence to industry standards.

CO3 (3): Proficiency in analyzing data using appropriate methodologies and tools demonstrates practical and procedural knowledge.

CO7 (2): Applying ethical principles during the research process reflects an understanding of ethical considerations and professional standards.

PO3: Entrepreneurial Mindset, Innovation, and Business Understanding

CO1 (2): Designing and executing a research project can involve innovative approaches and identifying opportunities for research.

CO4 (2): Evaluating literature and identifying gaps may require entrepreneurial thinking and creativity in framing research questions.

PO4: Specialized Skills, Critical Thinking, and Problem-Solving

CO1 (3): Independently executing a research project demonstrates specialized skills and problem-solving abilities.

CO3 (3): Analyzing data requires specialized technical skills and critical thinking.

CO4 (3): Evaluating literature and identifying gaps involves critical thinking and problem-solving.

PO5: Research, Analytical Reasoning, and Ethical Conduct

CO1 (3): Designing and executing a research project involves comprehensive research and analytical reasoning.

CO2 (2): Data collection is part of the research process, which requires analytical skills.

CO3 (3): Analyzing data effectively is a key component of research and analytical reasoning.

CO4 (3): Evaluating literature is an essential part of research methodology.

CO5 (3): Producing a well-structured report involves synthesizing research findings and adhering to academic standards.

CO6 (2): Presenting and defending research findings requires effective communication of research and analytical skills.

CO7 (3): Adhering to ethical principles in research ensures ethical conduct throughout the research process.

PO6: Communication, Collaboration, and Leadership

CO5 (2): Producing a clear and coherent research report demonstrates communication skills.

CO6 (3): Confidently presenting and defending research findings reflects strong communication skills and leadership in the academic context.

PO7: Digital Proficiency and Technological Skills

CO2 (3): Advanced skills in data collection and use of software tools demonstrate digital proficiency.

CO3 (3): Analyzing data using appropriate tools and methodologies reflects technological skills.

PO8: Multicultural Competence, Inclusive Spirit, and Empathy

CO7 (1): Applying ethical principles throughout the research process may involve an understanding of diverse perspectives and empathy.

PO9: Value Inculcation, Environmental Awareness, and Ethical Practices

CO7 (3): Ensuring ethical conduct in research is directly related to ethical practices and value inculcation.

PO10: Autonomy, Responsibility, and Accountability

CO1 (3): Independently managing and executing a research project demonstrates autonomy and responsibility.

CO6 (2): Presenting research findings and defending them before an academic audience reflects accountability and responsibility.