Course title: Stochastic Modelling

Course code: MEU 173	**No. of credits:** 4	**L-T-P:** 42-18-0	**Learning hours:** 60
Pre-requisite course code and title (if any): Elementary calculus and matrix algebra			
Department: Sustainable Engineering			
Course coordinator: Dr Deepty Jain		**Course instructor:** Prof. Prateek Sharma / Dr Deepty Jain	
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Course type: Core		**Course offered in:** Semester 1	

Course Description

As the world gets more crowded and technology continues to develop, environmental problems multiply. There are many aspects of these problems – economic, political, psychological, medical, scientific, and technological. Management of environmental systems is a complex task, which results in problems where decision making is required to be done under conditions of uncertainty. This is especially true in situations where the outcome of a "process/phenomenon" is subject to chance fluctuations and cannot be explained by the laws of cause and effect due to its dependence of several causative variables, some of which may or may not be known *a priori*. In order to bring necessary objectivity in decision making the quantification and treatment of this uncertainty is essential for developing stochastic models that can be used in the evaluation of practical problems. This course is intended to better prepare the engineers and scientists in grasping the fundamentals of stochastic processes and to develop skills to model these processes in the context of urban development, water resources planning, development and management.

Course objective

- Need for studying statistical methods
- Become mindful of a wide range of applications of stochastic modelling in the context of urban development, water resources management & decision making
- Understand the relation between probability and statistics
- Apply probability theory in reliability and risk analysis of systems

Course content

Module	Topic	L	T	P
1.	**Introduction** Mathematical models–deterministic and stochastic; stochastic processes in environment; the nature of random variables; populations and samples; parameters and statistics.	2		
2.	**Probability theory** Probability theory: probability concepts; properties of random variables; probability distribution functions and their applications – discrete and continuous distributions.	8	4	
3.	**Inferential statistics** Sampling theory, sampling distributions; parameter estimation, point and interval estimates; confidence interval estimation of–means, differences of means, proportions, difference of proportions, variances, ratio of variances sample size determination for different sampling designs Hypothesis testing–parametric and non-parametric tests (concerning means, differences of means, proportions, difference of proportions, variances, ratio of variances)	10	3	
4.	**Statistical distribution modelling** Probability plotting methods for different distributions; Goodness-of-fit tests – Chi-square, Kolmogorov-Smirnov and Anderson-Darling test; Methods of parameter estimation; simulation; applications.	8	4	
5.	**Correlation, simple regression and trend analysis** Correlation analysis: graphical analysis, bivariate correlation, covariance, correlation coefficient, distribution of correlation coefficient and its statistical significance. Simple regression analysis: assumptions and definitions, principle of least squares, regression parameters their distribution and statistical significance, applications in process description and prediction.	6	3	

	Trend analysis: Trend and seasonality analysis – parametric and non-parametric methods			
6.	**Risk and reliability analysis** Measures of reliability; reliability of systems: systems in series, parallel, mixed systems; uncertainty in reliability assessments; temporal reliability analysis; reliability-based design.	8	4	
		42	**18**	

Evaluation criteria

Minor Test 1: 20%
Minor Test 2: 20%
Tutorials: 20%
Major Test: 40%

Learning outcomes

- distinguish between a deterministic and stochastic process and situations under which the statistical methods are to be applied
- develop an intuitive statistical sense
- analyse, model and quantify uncertainty
- extract information and draw scientific inference from the data to solve problems related to urban development and water resources
- develop probabilistic models for predicting outcomes of stochastic processes
- apply the concepts of inferential and to take informed decisions under conditions of uncertainty

Pedagogical approach

The course will be delivered through class room lectures, discussion of case studies from original relevant research articles and hands on laboratory sessions on SPSS/Minitab statistical packages. The students would be encouraged to utilise on resources such R software.

Materials

Textbooks

- Ayyub B.M. and McCuen R.H. (2011). *Probability, Statistics and Reliability for Engineers and Scientists*. CRC Press, Boca Raton.
- Kottegoda N.T. and Rosso R. (2008). *Applied Statistics for Civil and Environmental Engineers*, McGraw-Hill, International Edition.

Suggested Readings

- Berthouex P.M. and Brown L.C. (1994). *Statistics for Environmental Engineers*, Lewis Publishers, CRC Press.
- Bryman, A. (2008). *Social Research Methods.* Oxford University Press.
- Gilbert R.O. (1987) *Statistical Methods for Environmental Pollution Monitoring*, New York, Van Nostrand Reinhold.
- Gibbons, R.D., Baumik, D.K., Aryal, S. (2009). *Statistical Methods for Groundwater Monitoring*. John Wiley & Sons, New Jersey, USA.
- Guthrie, G. (2010). *Basic Research Methods: An Entry to Social Science Research*. Sage Publications India Pvt Ltd.
- Haan C.T. (1977) *Statistical Methods in Hydrology*. The Iowa State University Press/Ames.
- Helsel, D.R. and Hirsch, R.M. (1991). *Statistical methods in Water Resources*. Elsevier, The Netherlands
- Kottegoda, N.t. (1980). *Stochastic Water Resources Technology*. John Wiley & Sons, New York.
- McCuen, R.H. (2003). *Modeling Hydrologic Change*. CRC Press LLC, USA.
- McBean E.A. and Rovers R.A. (1998) *Statistical Procedures for Analysis of Environmental Monitoring Data & Risk Assessment.* Prentice-Hall PTR, Upper Saddle River, NJ.
- McBride G.B. (2005) *Using Statistical Methods for Water Quality Management: Issues, Problems and Solutions*. John Wiley & Sons, Hoboken, NJ, USA.

Journals

- American Statistician
- Biometrika
- Environmetrics
- Environmental Modelling & Software
- Journal of Hydrology
- Risk Analysis
- Statistical Science
- Technometrics
- Water Resources Research

Additional information (if any)

Student responsibilities

The students are expected to submit assignments in time and come prepared with readings when provided

Course Reviewers

1. Prof Bilal M. Ayyub, Professor of Civil and Environmental Engineering, University of Maryland, College Park, USA.
2. Prof Richard H. McCuen, Professor of Civil and Environmental Engineering, University of Maryland, College Park, USA.