IIT Mandi
Proposal for a New Course

Course number	**:**	CE516
Course Name	**:**	Uncertainty Analysis in Civil Engineering
Credit Distribution	**:**	3-0-0-3
Intended for	**:**	B.Tech. 4th year/ M.S./ M.Tech./ Ph.D.
Prerequisite	**:**	Students are suggested to have a background on basic Engineering Mathematics related course at the UG level and the design and testing aspects in Civil Engineering (CE351: Design of Reinforced Concrete Structures or, CE402: Geotechnical Engineering II, or CE401: Design of Steel Structures or, CE354P: Building and Pavement Materials Laboratory, or equivalent)
Mutual Exclusion	**:**	'None'

Preamble:
Nothing in nature is definite but still one can find lot of predictions on strength of material, weather, soil property etc. How this is possible? This course gives you the background on answering such quantification which involves so many uncertainties. Thus, by pursuing this course the students will be equipped to find meaning from random data encountered in civil engineering. The course will deal in detail the qualitative and quantitative analysis on the data (strength parameters, material behavior curve, design loads, design procedures and data like earthquake etc.). The course also gives and exposure on to how possible this information can be further implemented to study a possible response. An effort will also be made to equip students to practically deal with such problems using examples involving computation. After this course, they would be well equipped to understand and develop probabilistic and reliability-based models for suitable design purpose.

1. Course Modules with quantitative lecture hours:

Module 1: The concept of 'Risk and uncertainty' in Civil Engineering (3 Hours)
Difference between deterministic and uncertain parameters, sources of uncertainties in civil engineering, classification and nomenclature of uncertainties (epistemic, aleatory, parametric, etc.), the concept of hazard, vulnerability and risk, Factor of Safety, lower and upper bounds.

Module 2: Uncertainty Quantification in Civil Engineering (10 Hours)
Understanding the examples of discrete and continuous random variables in civil engineering such as soil data, concrete strength data, other strength and design data, uncertainty quantification of such variables in form of mean, variance, COV, histograms, percentiles, box plots, correlation, skewness, scatter, probability distributions (PDF and PMF), expectations, moments, joint probability distributions, and extreme value theories.

Module 3: Introduction to Random Process (7 Hours)
Introduction to earthquake ground motions as random processes, and their basic statistical, temporal, and Spatial characterization including variograms, autocorrelation functions,

probability density, Interpolation methods (e.g., kriging), stationarity, ergodicity, and return period.

Module 4: Uncertainty Simulation & Propagation (**12 Hours**)
Simulating the random variables using the Monte-Carlo approach, Bootstrap method, example case-studies to understand the implications of these random input variables on the desired outcomes (e.g., structural response to random loads, case-studies from construction planning and management), derivation of the probability distributions of output variables, testing their goodness-fit, sensitivity analysis, first order second moment (FOSM) methods, and event tree analysis.

Module 5: Data interpretation and modelling **(6 Hours)**
Introduction to typical data from civil engineering experiments that needs to be modeled, identification of dependent and independent variables through example problems, Correlation analysis between the parameters in the model, identifying outliers, Functional form identification (Parametric, non-parametric), Performance evaluation, confidence interval, a brief overview on approaches to handling of missing information, Mixed-effects regression its significance and application.

Module 6: Advanced and Miscellaneous Topics **(4 Hours)**
The basics concepts of load, resistance, failure probability, factor of safety, and reliability, point estimate method, error propagation, Hasofer-Lind approach, Conditional probability, Bayes' law, Posterior distribution.

Laboratory/practical/tutorial Modules: N.A.

2. Text books:

1. H-S.Ang & W.H. Tang, Probability Concepts in Engineering: Emphasis on Applications to Civil and Environmental Engineering, Wiley, 2006.
2. Benjamin, Jack R., and C. Allin Cornell. Probability, statistics, and decision for civil engineers. Courier Corporation, 2014.

3. References:

1. Papoulis, A., Probability, Random Variables and Stochastic Processes, 3rd Ed., McGraw-Hill, 1991.
2. Jay L. Devore, Probability and Statistics for Engineering and the Sciences, Brooke & Cole, 2009.
3. Montgomery, Douglas C., and George C. Runger. Applied statistics and probability for engineers, John Wiley & Sons, 2007.
4. Fellin, W., Lessmann, H., Oberguggenberger, M., & Vieider, R. (Eds.). (2005). Analyzing uncertainty in civil engineering (pp. 51-72). Berlin: Springer.
5. Ross, S. M. (2004). Introduction to probability and statistics for engineers and scientists. Elsevier.
6. Soong, T. T. (2004). Fundamentals of probability and statistics for engineers. John Wiley & Sons.

7. Gordon A. Fenton, & Griffiths, V. D. (2008). Risk assessment in geotechnical engineering (pp. 381-399). New Jersey: John Wiley & Sons.
8. Crandall, S. H., & Mark, W. D. (2014). Random vibration in mechanical systems. Academic Press.
9. Oliver, M. A., & Webster, R. (2015). *Basic steps in geostatistics: the variogram and kriging* (pp. 15-42). Cham, Switzerland: Springer International Publishing.
10. Baecher, G. B., & Christian, J. T. (2005). Reliability and statistics in geotechnical engineering. John Wiley & Sons.

4. Similarity with the existing courses:
(Similarity content is declared as per the number of lecture hours on similar topics)

S. N.	Course	Course Code	Similarity Content	Approximate % of Content
1	Introduction to Probability	CS511	Definitions on probability, random vector and random process	9% (about 4 lecture hours of this course) *
2	Probability and Random Processes	EE534	Definitions on probability, random vector and random process	9% (about 4 lecture hours of this course)*
3	Statistical Data Analysis	MA605	Description on Statistical tests, and Goodness of fit	7% (about 3 lecture hours of this course)
4	Probability & Statistics	MA524	Basic definition of probability and statistics	9% (about 4 lecture hours of this course)*
5	Statistical Methods	HS550	Concept of moments, Basic definition of probability, Basic concept of Regression	12% (about 5 lecture hours of this course)*

* There is mutual overlap between these courses hence the percentage mentions have intercepts and not mutually exclusive.

6. Justification of new course proposal if cumulative similarity content is >30%:
None of the existing courses on probability and statistics talk about the specific civil engineering applications. In view of this, there is an urgent need of such a course for civil engineering UG and PG students.