CHEN/SENG 460/660, Quantitative Risk Analysis in Safety Engineering

Syllabus

Instructor: William J. Rogers, CHEN, JEB-426, <wjrogers@tamu.edu>

Class Sessions: JEB –108; Tue, Thu, 2:20 – 3:35 pm

Office Hours: Wed, Fri, 1:30 – 2:30 pm or by arrangement in JEB-426

Teaching Assist: TBA

Office Hours: TBA

Required Text: Norman Fenton and Martin Neil, *Risk Assessment and Decision Analysis with Bayesian Networks*, CRC Press, 2012

Required Text: Charles E. Ebeling, *An Introduction to Reliability and Maintainability Engineering, 2nd ed.*, Waveland Press, Inc., 2010

Resources: Materials from M. Modarres, *Risk Analysis in Engineering*, Taylor & Francis, 2006, and from other sources will be placed on the course website. Class PowerPoint presentations, solutions to exercises, quizzes, and tests, tables, figures, articles on the course website.
Risk in the News articles with current applications of risk analysis
Weekend Risk Reminders about concepts, methods, and questions

Prerequisite: Graduate or Senior UG status in engineering or science

Exams:

I	TBA
II	TBA
Final	May 7, 1:00 – 3:00 pm, JEB-108

Project dates: Project papers due date: TBA
Project presentations: TBA

Grading:

Exam 1	15%	increasing weight
Exam II	18%	
Final	25%	
Quizzes	10%	Solutions on website
Homework	12%	Solutions on website
Project	20%	

Objectives: Learn the fundamentals of a system approach to risk analysis and risk-informed decision making with an emphasis on engineering applications.

Materials: Exams will be based on all materials covered in class and practiced on assigned homework and quizzes. The course exams are weighted based on the concepts covered up to each exam.

Exams will test knowledge and ability to use methods practiced on exercises and homework to analyze industrial risk applications. Complex expressions and statistical tables will be provided on handout sheets to be used during exams.

Homework: Problems for work in teams and submitted as a team product with a team self evaluation will be assigned each week and will be due in class the following week for full credit. Solutions to problems will be posted on the course website.

Project: All students on each team will perform a term project to result in a paper and presentation based on applications of risk analysis as discussed and practiced in this course.

Class sessions: Class attendance is expected except for excused absences for which makeup quizzes will be given.

Quizzes are given about 1/week, often on the homework due date, to help students keep up to date with the class materials and to be better prepared for the exams. Solutions to quiz problems will be posted on the course website. Quiz credit is also for occasional questions and comments based on material discussed in class.

Success in this course is achieved through consistent work to keep up with the class materials and discussion, assigned homework problems, and assigned reading. This approach is designed to help each student and each team understand the concepts and apply to class discussions and applications. Class and homework exercises are especially important for learning and reinforcing probability models and predictive methods used to represent uncertainty in complex interactive systems and to support engineering decision-making under uncertainty and risk management involving uncertain events in real-life engineering applications.

Course Outline

Topic *Discussed and used throughout the course	Classes
Introduction Hazards, risk, risk analysis, decisions, probability, reliability	1
Risk Analysis (RA) System approach methods *RA structure, map; Analysis distributions viewed in risk profiles, risk matrices *Decision analysis, value of information, pre-posterior analysis, value of control *Probabilistic modeling of uncertain events for optimum decision-making *Bayes discrete and continuous models, for probability updating *Statistical correlations and cause/effect analysis; interdependencies *Data engineering: confidence interval analysis and data needed *Traditional statistics compared with Bayesian statistics and networks	9

*Uncertainties in data, information, models, scenario outcomes
*Near misses, unusual occurrences, precursor events, weak signals
Hierarchical Bayesian models, Bayesian networks (BNs)
Logic modeling, fault trees, event trees
Bayesian network construction, software calculation, interpretation
Diagnostic, abductive, predictive, intercausal reasoning
Dependent failures: BNs and β-model of common cause failure

Performance Assessment of Engineering and Organizational Systems Reliability, Maintainability, and Availability distribution analysis Time independent, time dependent, and conditional hazard rates Covariate and physical models Markov analysis, state dependent systems Reliability testing and model parameters updating Reliability, availability, and maintainability distribution models of components and systems including exponential, Weibull, binomial, beta, Poisson (homogeneous and non-homogeneous), gamma, normal, lognormal, empirical data population models	6
Human reliability modeling, SHARP method with quantitative models and BNs. Human and Organizational factors	1
Uncertainty analysis Uncertainty propagation, epistemic and aleatory uncertainties Consequence analysis on projects Aloha, Phast, Probit, Multi-Energy, Baker-Strehlow models	1
Risk contributors Risk drivers and metrics. Risk ranking	1
Risk values, risk acceptance criteria Individual and societal risk criteria, ethics, citizen engineer	1
Risk Management Risk-informed multi-criteria and multi-attribute decision analysis Dynamic predictive system management with continual system monitoring, Updating, testing of component and system behavior forecasts Engineering system and organizational system indicator aggregation in BNs to identify weak signals, outcome precursors, trends, and actions for support of optimum decisions to manage risk within acceptable limits	4
Risk communication with stakeholders and community; Auditing; Safety culture; Risk perception; Risk/Benefit, Risk conversion factors	1
Guest Lecture on risk analysis and system approach topics	1
Exams and reviews	2
Total Class Sessions, 75 minutes each	28

Classroom Attendance

Students are expected to arrive in the classroom for the class session to begin on time as is required for professional assignments. Late arrivals or missing class sessions can result in a low quiz grade average. If, due to circumstance, a student is not able to arrive on time, late arrival to class is better than missing the entire class. Students missing class time should consult their team members, other class students, the course website, teaching assistant, and instructor for guidance concerning missed concepts and materials.

Classroom Participation

Participation and questions in class discussion are encouraged. We will all learn more effectively from each other if we exercise what we encounter and analyze from different points of view and from a variety of experiences.

Laptops and Cell Phones

The use of cell phones and laptops during class is a distraction from class participation and is not acceptable. See your instructor if you have a special need for laptop use during class.

Classroom Decorum

As stated in Section 21 of the **TAMU Student Rules**, "Texas A&M University supports the principle of freedom of expression for both instructors and students. The university respects the rights of instructors to teach and students to learn. Maintenance of these rights requires classroom conditions that do not impede their exercise. Classroom behavior that seriously interferes with either (1) the instructor's ability to conduct the class or (2) the ability of other students to profit from the instructional program will not be tolerated. An individual engaging in disruptive classroom behavior may be subject to disciplinary action. See 24.3.12."

If you experience issues concerning classroom behavior, please discuss with the instructor or with the teaching assistant. Also, you are encouraged to bring concerns about the course to the attention of the instructor or the teaching assistant. Thank you for your consideration and dedication to help make the classroom environment respectful, stimulating, and comfortable for all students.

Americans with Disabilities Act (ADA) Policy Statement

The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other items, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation for their disabilities. If you believe you have a disability requiring an accommodation, please contact Disability Services, in Cain Hall, Room B118, or call 845-1637. Additional information is available at http://disability.tamu.edu.

Academic Integrity Statement and Aggie Honor Code

"An Aggie does not lie, cheat, or steal or tolerate those who do."

Please consult the Honor Council Rules and Procedures on the web at http://aggiehonor.tamu.edu.

Plagiarism

Use of another person's ideas, processes, results, or words requires appropriate credit or references to the authors. Plagiarism is forbidden, because it reduces trust in safe and reliable communication of research among authors and scholars. For questions about plagiarism, consult the TAMU Student Rules under "Scholastic Dishonesty" or "Academic Misconduct" at http://aggiehonor.tamu.edu/Student%20Rules/definitions.html

Team Objectives and Guidelines

Students will work on and submit homework assignments and team projects in teams of 3 - 5 students. Three objectives of working in teams are:

1. To practice and gain experience in working with others, because this is the most common mode of operation in professional engineering.
2. To learn from each other in a dynamic work environment, to expand individual perspectives, to pool individual knowledge to maximize the utility and quality of individual work, and to promote continual and cumulative benefits from a variety of learning modes.
3. To benefit from the insight, analysis, and evaluation of each team member together with the dynamics of team interaction, communication, and leadership.

The greater the interaction among your team members, the more effectively these objectives will be achieved. An objective is not just to divide up the work, so that each team member has less to do. This approach defeat the primary advantages of interactive teamwork and will result in poor performance on exams.

Each team will have a team leader. For maximum benefit and experience, the team leader position should rotate frequently at the discretion of the team. You should decide at your first team meeting who will be the leader and for how long.

Team Leader – is responsible for insuring that everything gets done. He or she will coordinate teamwork and insure that everyone contributes. Coordination includes:

Scheduling Team Meetings - The team should meet together at least once and preferably twice each week to discuss the assignments, compare and check work. Additional communications can be by e-mail or telephone.

Assigning Specific Tasks to Team Members –Task assignments may include doing calculations, explaining principles, or checking someone else's calculations. Assign responsibilities and tasks for the semester project.

Setting Schedules - The leader must set deadlines and insure that they are met. Schedules include time for every team member to review and check all the work done on every assignment with feedback and corrections prior to submission.

Evaluating Team Activities - The team leader for a given week will evaluate the team performance in completing the homework on an included Team Evaluation form that will be the basis for 20% of the homework grade.

Obtaining Signatures - Each student will sign the teamwork evaluation form to confirm that that each problem has been understood and performed or reviewed. Signatures of team members should apprear on all documents submitted for the team projects.

Team Members – will perform a variety of tasks relative to the assignments and term projects including researching a topic, setting up or solving a problem, checking calculations, or looking up references or data. Every member of the team must contribute in some way to every assignment and every major component of the term project, even if it involves only checking the work that others have done. Every student is expected to understand every problem on every assignment, and will demonstrate that understanding individually on quizzes and exams. :This understanding will be greatly facilitated and reinforced through discussion with team members during regular team meetinds.

Communication and persistence are the keys to effective teamwork!

Team Self Evaluation – Each homework assignment will include a teamwork self evaluation for 20% of the homework grade. Also, a team member self evaluation of work on the homework assignments and work on the team project will be conducted and submitted by each team member near the end of the semester.

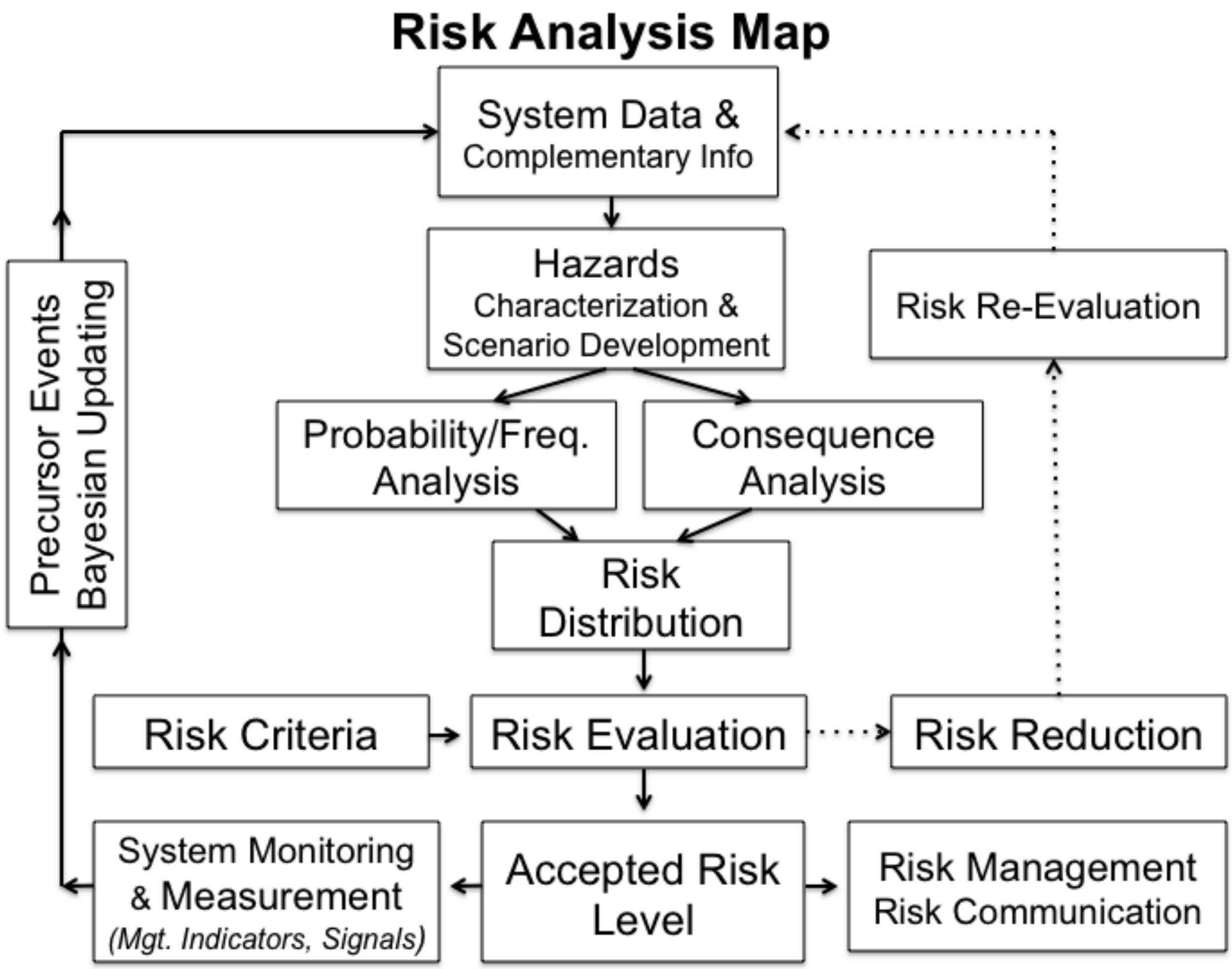
Course Goals and Learning Outcomes

Learn how to perform a system approach to risk analysis, reduce risk cost effectively within acceptable ranges, manage risk with acceptable limits, make incremental improvements in system performance and reliability, make risk/gain-informed decisions under uncertainty to benefit the organization and the community, and communicate and defend decisions under uncertainty that affect the organization personnel, other stakeholders, and the public, which benefits from and supports the products of your company.

Course Objectives

This course provides the opportunity to learn about risk, the applications of risk involved with industrial activities, and how to practice risk-informed decision-making and risk management. Because engineering is a systems decision-making enterprise, a systems decision-making way of thinking is used throughout the course both with regard to the engineering system and with regard to the organization.

Risk analysis consists of identifying, characterizing, reducing, managing, and informing others about the nature, magnitude, probability, and uncertainty of credible outcome events. Therefore, an understanding of methods and tools to represent and quantify uncertain events is essential. These tools include the models and methods of probability to quantify uncertain events and statistics to evaluate empirical data, identify population models via descriptive statistics, obtain model parameters via least squares fitting and maximum likelihood, test models, and update model parameters from current system monitoring to support optimum component and system reliability forecasts. Quantification of risk and forecasts of potential failure occurrences are essential for all risk analysis applications.



Risk assessment and good decision-making for increasingly complex systems is increasingly needed for design, manufacturing, operation, maintainability, management, and regulations. The risk analysis approach facilitates evaluation of calculations and results so that the benefits and costs of each decision alternative can be weighed and balanced. Open discussion and analysis of decisions among team members and with stakeholders can help to improve the organization safety culture based on optimum risk management and also to increase credibility and public confidence in plant leadership and risk management.

This course will analyze how uncertainty and risk levels can be reduced and managed within tolerable ranges. Zero risk results in no activities, and some risk is always necessary, so a systematic method is needed to provide the basis for cost effect control of risk within acceptable levels. This needed approach is provided by risk assessment. Another approach still used in design and management of systems, however, is to reduce risk through over design and defense in depth using, for example, large ad hoc safety margins that can result in excessive costs or with risk insufficiently reduced or with risk transferred elsewhere in the system or in the organization. Risk analysis and optimum engineering decisions result from the fundamentals to analyze all relevant data and predict overall system behavior under industrial conditions.

The course topics follow those listed on the course syllabus, and homework assignments are based on lecture topics and materials. Applications of class materials are to be consistently practiced and reinforced by class exercises, homework problems, and student projects, which culminate in written reports and class presentations of the team projects. In addition to applications of engineering principles, concepts of system management, teamwork, and individual responsibilities of citizen engineers are stressed, as well as the importance of the empirical approach of measurement, and the assessment of calculated values.

Students in Teams fulfill the homework assignments and perform a major project as a team product. Homework papers and projects are therefore submitted as team products, and the teamwork dynamics of each team are self-evaluated weekly to promote continual and cumulative benefits from team learning. The main purpose of working in teams is to enable each student to learn from the experience, knowledge, and the ideas of the other team members and to learn through the dynamics of team interaction, communication, and leadership.

Course Resources

Norman Fenton and Martin Neil, *Risk Assessment and Decision Analysis with Bayesian Networks*, CRC Press, 2012

This recent book provides the mathematics and software needed for an introduction to the flexible and versatile Bayesian networks, which are presented clearly with excellent and interesting examples to build motivation for students to learn how to construct Bayesian networks and use them in risk applications for diagnosis, prediction, and calculations involving discrete or continuous distributions.

Charles E. Ebeling, *An Introduction to Reliability and Maintainability Engineering, 2nd ed.*, Waveland Press, Inc., 2010

This is an engaging and up to date book on reliability, availability, and maintainability distribution models needed for risk assessment and management.

Modarres, M., M. Kaminskiy, V. Krivtsov, *Reliability Engineering and Risk Analysis, 2nd ed*, Taylor & Francis, 2010 (Modarres, RERA)

This book focuses on practical methods for evaluating and managing reliable systems within acceptable levels of risk.

Jordaan, I., *Decisions under Uncertainty, Probabilistic Analysis for Engineering Decisions*, Cambridge University Press, 2005 (Jordaan, DUU)

This book provides a clear and coherent approach to engineering decision-making and an intuitive approach for understanding and estimating probability values needed for risk assessment and decision-making.

Modarres, M., *Risk Analysis in Engineering*, Taylor&Francis, 2006 (Modarres, RAE)

This book is a comprehensive book on risk analysis to supplement the risk and reliability methods discussed in RERA. Assigned reading will be placed on the course website.

Ayyub, B.M., *Risk Analysis in Engineering and Economics*, Chapman & Hall/CRC, 2003.

Provides a good introduction to risk, with emphasis on economic applications, and to decision making.

Making Acute Risk Decisions with Chemical Process Safety Applications, CCPS, AIChE, 1995 (AIChE, 1995)

This book concerning risk decision-making has examples and case studies from the chemical industry.

Ang, A.H-S. and Tang, W.H., *Probability Concepts in Engineering, 2nd ed*, Wiley, 2007 (Ang, PCE)

An excellent, practical source for probability methods and probability distributions with engineering examples

Ang, A. H-S. and W.H. Tang, *Probability Concepts in Engineering Planning and Design, Vol 2*, Wiley, Decision, Risk, and Reliability, 1990 (Ang, PCEPD)

An excellent source for decision analysis and value of information as part of the decision process with many decision-making examples from industry

Savage, S.L., *The Flaw of Averages, Why we Underestimate Risk in the Face of Uncertainty*, Wiley, 2009

Uses graphic methods to teach the importance of using distributions instead of only point values, such as mean or median values, for decision-making.

Clemen, R.T. and T. Reilly, *Making Hard Decisions*, Duxbury, 2001

Presents a broad but clear approach to decision making with many examples.

Hammond, J.S., R.L. Kenney, and H. Raiffa, *Smart Choices*, Harvard Business School Press, 1999

An enjoyable and well-founded discussion about making optimum decisions.

Holloway, C. A., *Decision Making Under Uncertainty, Models and Choices*, Prentice-Hall, 1979

A very clear and readable introduction to decision analysis with interesting examples and applications.

Hubbard, D.W., *The Failure of Risk Management*, Wiley, 2009

This engaging book dramatizes current weaknesses of risk management and what could and should be done to improve decision-making and mange risk more effectively.

Hubbard, D.W., *How to Measure Anything, 2nd ed*, Wiley, 2010

Focuses on the importance of measuring significant factors that benefit a system or help to develop a highly effective risk management program.

Christensen, R., W. Johnson, A. Branscum, and T.E. Hanson, *Bayesian Ideas and Data Analysis, An Introduction for Scientists and Statisticians*, Taylor&Francis, 2011

Provides an incisive discussion of the power and applications of Bayesian reasoning and statistical inference to make accurate predictions and fulfill a crucial objective of engineering and science.

Neapolitan, R.E., *Learning Bayesian Networks*, Pearson Prentice Hall, 2004

A comprehensive textbook introduction to applications of Bayesian networks for scientists, engineers, and other practitioners of system behavior understanding and management.

Fischholf, B. and J. Kadvany, *Risk, a Very Short Introduction*, Oxford, 2011

This introduction of risk provides a pithy overview of psychological contexts in which risk is perceived, measured, managed, and endured.