

RISK MODELING, ASSESSMENT AND MANAGEMENT

**Final Report
MBTC 2061**

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1. INTRODUCTION

Since the events of September 11th 2001, there has been a lot of emphasis placed on increasing the security of our nation's infrastructure. The federal government has increased spending on homeland security by \$14 Billion over pre-September 11th funding levels. Total expenditures on Homeland Security in the 2003 Budget are on the order of \$31 Billion dollars. A significant amount of that funding will be spent on securing our transportation infrastructure. Key to spending those dollars wisely will be the development of an adequate risk analysis, mitigation and management plan for each of the various transportation sectors. While the majority of focus has been on the Airline industry, the other elements of the transportation sector (trucking, rail, ship) are at risk to terrorist activity. In order to properly expend those valuable resources, future managers and engineers must understand the components of risk, how to analyze, mitigate, and manage it. Examining the curriculum of the transportation program as well as the curriculum of the other supporting departments in the University, one quickly notices a lack of a formal course on risk modeling, assessment, and management in the design, acquisition, implementation, and operation of these types of systems. Thus, graduates of these programs will be entering their field with a lack of understanding of risk and the tools necessary to model and manage it.

The objectives of this effort will be to develop a senior/first year graduate level course on risk analysis. This course will begin with an introduction to systems engineering and an illustration of where and when risk analysis tools are used in the various stages of a systems life cycle. The course will identify methodologies for identifying risk, the role risk plays in each of the different phases of a transportation systems life cycle. Special emphasis will be placed on security risks to the transportation industry. The course will illustrate tools for making decisions under risk, techniques for trading off multiple objectives, as well the probability and statistical tools necessary to build and analyze models that can assist in identifying risks to the systems under study. Applicable case studies from the transportation literature will be developed and utilized in the course to illustrate the various tools and techniques to the students.

2. PROJECT TASK DESCRIPTIONS

We utilized the systems engineering and management process to accomplish the project goals within the budgeted time frame. The project started with a comprehensive review of the relevant transportation and risk analysis literature and concluded with an initial set of lessons and case studies on the modeling, analysis and management of risk for a variety of transportation systems. During the course of the project, we made sure that the project is relevant to the issues associated with real-life transportation systems.

The following lists the sequence of tasks we followed to construct the first offering of the Risk Analysis course (INEG514V) in the Industrial Engineering Department.

Phase 1. First, a comprehensive review of the transportation, homeland security, and risk analysis literature was accomplished. The goal was to build a collection of relevant articles for use in the development of the course. The focus was on finding articles that demonstrated the use of risk analysis tools and techniques on real-world transportation systems. Second, a comprehensive review of relevant text books on risk analysis and modeling was conducted. This review included examining applicable texts on transportation modeling and analysis as well as homeland security.

Phase 2. In this phase, we begin by defining the problem. We performed a formal needs analysis, stakeholder's analysis and futures analysis in order to develop the course objectives and establish an appropriate course outline.

Phase 3. In phase three, we focused on the detailed design of the course. As part of this process, a text book was selected. Detailed lesson objectives were constructed and appropriate lesson content was designed to meet those objectives. Appropriate assessment tools and techniques were identified and incorporated into the course.

Phase 4. The focus here was on the development of a set of case studies that are designed to challenge the students and give them practical experience in using the risk analysis tools and techniques they have learned on a set of relevant transportation problems. The goal was to develop several different case studies that could be utilized throughout the course.

Phase 5. The course was offered during the spring semester 2006. Student feedback was solicited throughout the conduct of the course. At the end of the semester, the assessment data and student feedback was summarized and will be used to make changes where appropriate for the next offering in the Spring of 2009

3. COURSE OBJECTIVES

This course began with an introduction to systems engineering and an illustration of where and when risk analysis tools are used in the various stages of a systems life cycle. The course identified methodologies for identifying risk as well as the role risk plays in each of the different phases of a transportation systems life cycle. Special emphasis will be placed on security risks to the transportation industry. The course illustrated a variety of tools for making decisions under risk, techniques for trading off multiple objectives, as well the probability and statistical tools necessary to build and analyze models that can assist in identifying risks to the systems under study. Applicable case studies from the transportation literature were utilized in the course to illustrate the various tools and techniques to the students. Students were required to perform a comprehensive project where they applied some of the tools and techniques to a system of their choosing.

Upon the completion of the course the students should be able to:

- Explore risk management practices, and understand risk management concepts
- Explain the fundamentals of probabilistic risk assessment.
- Discuss the qualitative and quantitative aspects of system analysis and uncertainty quantification.
- Integrate risk management into project planning

- Identify project risk, and understand and identify risk factors
- Manage risk assessment goals and identify the advantages of an assessment methodology
- Use simulation tools and statistical techniques to perform a risk analysis, and use knowledge-based risk management
- Formulate and apply risk management approaches
- Identify the project environment, and manage stakeholder groupings and categories
- Use problem solving techniques and apply risk identification and filtering.
- Apply risk analysis techniques to engineering applications.
- Read and analyze case studies that utilize risk analysis techniques.

4. LITERATURE RESEARCH

The literature search consisted of two parts. First, we searched the literature to identify an appropriate text book for the class that was consistent with our learning objectives for the course. Second, relevant case studies were identified from the literature and a subset used as part of the course.

4.1 Literature Search for Textbooks

A brief review analysis of the books we considered for the course is provided below:

- *Risk, Crisis and Security Management by Edward P. Borodzicz* – This book provides a good general overview of risk but lacks the basic mathematical concepts of risk analysis. The mathematical tools are necessary elements if we expect students to perform quantitative risk analysis of complex technological systems.
- *Probability Risk Assessment and Management for Engineers and Scientists by Hiromitsu Kumamoto and Ernest J. Henley* – This book focuses primarily on

probabilistic risk assessment and the mathematical formalisms necessary to perform quantitative risk analysis. It does an especially nice job of explaining the use of fault tree analysis. The major weakness we saw in this book is that it lacked recent examples which will help the students in understanding the application of risk analysis techniques, especially in the transportation sector.

- *Risk Modeling, Assessment and Management by Yacov Y. Haimes* – This book was the most comprehensive, as it could cater to both the undergraduate students as well as graduate students. It incorporated real world examples and case studies to illustrate the analytical methods under discussion; the book presents basic concepts as well as advanced material, avoiding complex mathematics whenever possible for the easy understanding of the students.
- *Introduction to Risk Analysis by Daniel Byrd and Richard Cothorn* – This book provides a comprehensive review of risk analysis as it applies to the nuclear, chemical and food industries. It focuses on exposure assessment, dosimetry, epidemiology, toxicology and ecological risk. It did contain many of the standard analysis techniques but was deemed to be too specialized for our purposes.
- *Risk Analysis: A Quantitative Guide, 2nd Edition by David Vose* – is an excellent reference for basic quantitative models for risk assessment. One of the key strengths of this book is its organization and introduction of the basic modeling skills associated with building probabilistic risk assessments. This book does address specific uses of these tools in project management, and animal and food safety. There is limited discussion of the use of these techniques in engineering and transportation settings.

- *Foundations of Risk Analysis: A Knowledge and Decision-Oriented Perspective* by Terje Aven – this book focuses on the key steps in creating a risk estimate for a system. It addresses both classical statistics as well as Bayesian approaches to estimating and analyzing risks. This is a very good technical overview of the general concepts but lack significant detail, no problems for students, and limited examples.
- *Risk Analysis: Assessing Uncertainties beyond Expected Values and Probabilities*- this book is newer and more comprehensive than the previous book. The author begins with an introduction to what risk analysis is, a comprehensive discussion of vulnerability, and an overview of risk analysis methods. The majority of the book is a collection of example applications. Relevant examples include safety measures for road tunnels, risk analysis for offshore installations, and risk analysis for a municipality. Like the author's other book, there are no student exercises provided and limited details on many of the techniques. This would make a good companion to a more comprehensive book that focuses on the details of implementing the various tools and techniques for performing a risk analysis.

Based on our analysis, we selected the second edition of “Risk Modeling, Assessment and Management” by Yacov Y. Haimes as the text book for the first offering of the course. Also according to a brief survey of engineering programs with courses on risk, many of the schools are presently using this book at both the undergraduate and graduate level.

4.2 Literature Review : Case Studies

This section briefly describes the case studies that we found relevant to the course materials, informative and presented a complete and thorough application of the risk methodologies studied to real-world problems.

A Unified Framework for Multi criteria Evaluation of Transportation Projects

Jennifer S. Shang, Youxu Tjader, and Yizhong Ding **Source:** *IEEE Transactions On Engineering Management*, Vol. 51, No. 3, August 2004

This paper deals with Transportation project selection. The authors have compared traditional hierarchical analysis tool with their Analytical network process (ANP) to evaluate transportation projects in Ningbo one of the China's oldest cities. The authors state that ANP is better than the conventional evaluation methods as it allows feedback and interdependence among various decision levels and criteria.

Ningbo plans to spend about \$2.4 billion on the transportation developments for governments five-year plans. Several transportation projects are under consideration, therefore an efficient evaluation framework which should be comprehensive and address a wide range of quantitative and qualitative long-terms and short-terms factors.

A nine member group from various government and local administrators was formed. The committee decided that the chosen transportation project should improve the productivity of the Ningbo metropolitan areas, improve accessibility, reduce transportation-related pollution and allow future expansion. The committee recommended Analytical network process (ANP) model for this project which was a

general case of Analytical hierarchical process (AHP). The basic difference between the two was that AHP uses unidirectional hierarchical relationship to model decision levels, while ANP allows interaction among subnets and among criteria within a cluster. The framework consisted of benefits, opportunities, costs, risks as the major deciding criterion or subnets on which the main goal which was “selecting best transportation project” depended. The importance of each subnet is first assessed by pairwise comparison of the subnets. Then the committee assesses the dependency of one cluster over the other in the same subnet by a pairwise comparison with respect to the subnet goal. The authors quote an example, for instance, the clusters under “benefits” subnet are pairwise compared with the goal to “maximize benefits”. The criteria are ranked according to their priorities based on the weight reached by an agreement of all the group members. Further, a supermatrix is formed representing the influence of these factors on the alternatives. Sensitivity analysis of the model is carried out and the best project is selected. One major drawback of this approach is that when the model becomes large, it becomes time-consuming, yet a versatile project proposed like this is likely to reduce the chances of poor decisions when billions of investments dollars are at stake.

Methods Toward Supply Chain Risk Analysis

Roshan R. Pai, Venkata r. Kallepalli, Reggie J. Caudill, MengChu Zhou; *IEEE 2003*

With the recent terrorist attack on World Trade Center, the vulnerabilities of the economic infrastructure have been exposed. Therefore it has become necessary to assess the vulnerability of business supply chains to sustain business in the present risk

environment. This paper reviews existing techniques used in decision making for risk and presents a framework for assessing business risk in supply chain networks.

The authors state that to analyze any risk environment it is essential to know the modes of damage to the assets and probability associated with each. A complete causal tree structure and an inference engine is required to determine the most probable risk path and relative probabilities of occurrence. According to authors, the inference can be done using three techniques – Bayesian networks, Fuzzy logic and Hybrid networks. The use of these three techniques largely depends on the type of data under study i.e., whether it is qualitative or quantitative, continuous or discrete or combination of them.

To materialize their theory, the authors carried out an initial case study using Bayesian network for inferring. The initial phase of the case study involved study of the most widely used materials by the Department of Defense (DoD) – Trinitrotoulene (TNT). The supply chain network consisted of two TNT recovery plants in Indiana and Oklahoma; one storage facility; one munitions manufacturing plants in Tennessee; two storage plants depots in Kentucky and Utah. All the elements of the supply chain are modeled as either production node or logistics node. The recovery units, storage units, manufacturing plant and the depot are modeled as production node. The material transfer between the production nodes is modeled using logistics nodes. Each of these units has well defined assets and threats. The three threats that affect these assets are contamination due to terrorist act, disruption from natural disaster, terrorism; and corruption due to terrorist activity. Threat-asset pairs are generated to get an idea about the threat posed from these threats. The probability of occurrence of threat is estimated. The percentage damage to the asset which is consequence is defined. The Risk Factor which is defined

as expected value of the loss to assets from the threat is estimated. The risk factor generated and compared with the acceptable limit. If risk factor is higher countermeasures are taken till it is below the acceptable level. This case study though being in the preliminary stage enhances our understanding on the complexity of the problem.

Virginia's critical infrastructure protection study

Jones, E.V. (Dept. of Syst. & Inf. Eng., Virginia Univ., Charlottesville, VA, USA);

Lyford, V.J.; Qazi, M.K.; Solan, N.J.; Haimes, Y.Y. **Source:** *Proceedings of the 2003*

IEEE Systems and Information Engineering Design Symposium (IEEE Cat.

No.03EX653), 2003, p 177-82

Virginia's critical infrastructure protection study implements risk assessment and management methodologies upon eight case studies located in the commonwealth of Virginia (Lyford et. al, 2003). These case studies were primarily by the influenced by 9-11 because of the growing national concern involving infrastructures. The output of this report is intended to be used by Virginia Department of Transportation (VDOT). The study involved risk assessment and management methodologies; and further development of computer-based risk management tool.

The eight critical assets analyzed in this study included one Intelligent Transportation System (ITS) traffic-control center, two major interstate interchanges, three bridges, one bridge-tunnel and one tunnel. The project first involved risk assessment analysis of each of the sites. The general methodology followed for this process was the Risk Filtering, Ranking and Management (RFRM) methodology developed by Yacov Y. Haimes, Stan

K. Kaplan and James H. Lambert (2002). Phase I of RFRM involved Hierarchical Holographic Modeling (HHM). Phase II involved filtering the HHM to eliminate the unimportant areas of risks. Further threat scenarios were defined. In phases III-V, the most severe threat scenarios were defined by forming a risk matrix. Next step was risk management. In this step risk management options are generated and evaluated. The management options are generated by considering the list of risk scenarios. The cost-benefit analyses are carried out and a small set of Pareto optimal management options are generated. These studies are informative and beneficial and are used in the development of computer-based risk management tool.

Risk Assessment for Asbestos-Related Cancer from the 9/11 Attack on the World Trade Center

Nolan, Robert P., Ross, Malcolm, Nord, Gordon L., Axten, Charles W., Osleeb, Jeffrey P., Domnin, Stanislav G. Price, Bertram, Wilson, Richard; *Journal of Occupational & Environmental Medicine*; Aug 2005, Vol. 47 Issue 8, p817-825, 9p

The main objective of this case study was that the authors intended to estimate the lifetime risk of asbestos-related cancer for residents of New York City's Lower Manhattan region due to the asbestos released in the air by 9-11 attack on World Trade Center.

Six representative settled dust samples were collected at least 6 days after 9/11. Each of these samples was analyzed using powder x-ray diffraction, polarized and electron microscopy. Cancer risk was assessed using an asbestos risk model that differentiate

asbestos fiber-types and the US Environmental Protection Agency's (EPA) model that does not differentiate fiber-types and lung cancer and mesothelioma risks. The studies were based on the assumptions that the dust particles sampled were representative of the dust from collapse; accurate estimate of airborne asbestos concentrations was established back to 9/11; and the risks of mesothelioma and lung cancer were carried assessed separately rather than as an aggregate of asbestos-related cancer.

From the results it was concluded that the maximum number of asbestos-related cancers is less than one case over the lifetime of the population for the risk model that is specific for fiber-types and 12 asbestos-related cancers with the EPA's model. Therefore, it was safe to conclude that the risk of developing cancer from the exposure of asbestos was negligible.

Risk analysis for road and rail transport of hazardous materials: a simplified approach

Bubbico, R. (Dipt. di Ingegneria Chimica, Univ. di Roma "La Sapienza", Rome, Italy);
Di Cave, S.; Mazzarotta, B. **Source:** *Journal of Loss Prevention in the Process Industries*, v 17, n 6, Nov. 2004, p 477-82

The authors of this paper propose the use of a product databank for Transportation Risk Analysis for road and rail transport of dangerous goods. The typical procedure for carrying out transport risk analysis will include identifying possible release scenarios and weather conditions, the probability of occurrence of each release scenario, probability of evolving of the release scenario into a possible outcome such as pool-fire, toxic cloud etc

for a product. Consequence analysis is performed to estimate the impact areas for each outcome case and weather condition: the obtained results are incorporated in a product data bank. Risk calculations are performed to determine the risk based on the number of trips carried out for each weather condition.

The authors considered a case study which consisted of road transportation of ethylene oxide from industrial unit near Priolo to a ferry terminal of Messina in Sicily. Ethylene oxide is a highly flammable gas which can explode in the absence of the oxygen. Ethylene oxide transportation takes place all the year requiring 450 trips per year due to different weather conditions. The F-N curves relative to the societal risk is plotted which showed that the risk is not too high. By substituting road with rail transportation the authors noticed considerable reduction in the risk. The authors state that the use of TRA as a decision tool will be limited as it is a rigorous approach and requires long calculations and analysis. Therefore it should be used to obtain rapidly relevant risk measures which can be used for the first assessment of the case.

Modeling Risk in the Dynamic Environment of Maritime Transportation

B.A. Peters, J.S. Smith, D.J. Medeiros, and M.W. Rohrer, eds. **Source:** *Proceedings of 2001 Winter Simulation Conference*

The Washington State Ferries (WSF) is the largest ferry system in the United States. Accidents involving Washington State Ferries are rare events. Due to the low probability of the occurrence of such accidents, large accident databases are not available for a standard statistical analysis of perceived risk factors. The authors have therefore proposed

a modeling approach that uses Simulation to capture the dynamic environment of changing environments.

Some of the tasks assigned to a consultant team in the WSF to assess the adequacy of passenger and crew safety, evaluate level of risk present in the WSF system, to develop recommendations for prioritized risk reduction measures. The Simulation was used to accurately represent the operation of the WSF vessels and the environmental conditions at any given time. The Simulation will model the dynamic nature of WSF risk assessment. The system risk at any time is posed by the each of the vessels in the system. As the time changes, the level of the risk in the system also changes. These risk interventions that change the dynamics of the system can be evaluated using simulation. Two cases were modeled. In scenario one there was no Chinkoo class ferry whereas in scenario 2 there was one Chinkoo class ferry. There was a third scenario which consisted of two high speed Chinkoo class ferry. The average return time of a collision was compared for each of the three cases. It was found that the number of expected number of collisions was increased in the scenario 3. However, the average collision probability per interaction for the Chinkoo was less than that of the older – passenger ferries. Various risk models were built to represent multiple scenarios reflecting past, present and future operating procedures of the ferry system. These risk models were capable of answering the questions posed by the WSF regarding risk assessment of the ferry system.

In addition to the above case studies, several case studies were used as part of course examinations. These case studies were taken from the Risk analysis literature, primarily from the Journal of Risk analysis. We focused on two special issues, the one on homeland security and terrorism, as well as one on risk in the nuclear industry.

5. COURSE DEVELOPMENT METHODOLOGY

This section will focus on the methodology used in designing the Risk Analysis course. After selecting the appropriate book, we developed the course in the following order:

- First we prepared a course outline for all the topics to be covered from the book.
- Second, we prepared power point presentations for each of the chapters that we planned to use. These slides summarized the important details for each of the chapters covered.
- Third, we prepared home work and exam questions for each chapter so that the students could apply the concepts they have been taught.

5.1. Course Overview - Summary of each chapter

Part I of the selected text book covers the “Fundamentals of Risk Modeling, Assessment, and Management” which includes chapter 1-7. It focuses on the philosophical, conceptual and decision making aspects of risk analysis. It addresses fundamental concepts of modeling, optimization of systems under conditions of management, and presents commonly known and newly developed risk analysis methodologies.

Chapter 1, “The Art and Science of Systems and Risk Analysis”, gives a general overview of risk analysis in the broader context of systems engineering. Haimes quotes examples from Stephen Covey’s book “The Seven Habits of Highly Effective

People” and relates them to system engineering principles and further relates them to risk analysis. It covers the basic definitions of risk and risk management. It familiarizes students with the sources of failures and concepts involving perception of risks.

Chapter 2, “The Role of Modeling in the Risk Analysis Process”, introduces students to the fundamental building blocks of mathematical models for managerial decision making. The mathematical models covered are linear vs. non linear, deterministic vs. probabilistic, static vs. dynamic and distributed parameters vs. lumped parameters. This chapter illustrates the 5 basic risk assessment steps; risk identification, risk quantification and measurement, risk evaluation, risk acceptance and avoidance and finally risk management.

Chapter 3, “Identifying Risk through Hierarchical Holographic Modeling”, addresses the HHM philosophy for risk identification and contributions made by the social and behavioral scientists in the field of risk analysis. It covers the concepts of multi level decomposition, hierarchical overlapping co-ordination and product-plant decomposition. The holographic hierarchy modeling includes the discussion of impact of HHM on planning, HHM for risk identification and temporal-based HHM structures. It also covers the concepts related to ranking of risks such as the risk-ranking hierarchy.

Chapter 4, “Decision Analysis”, offers an overview of the fundamentals in decision analysis and the construction of evidence-based probabilities for use in decision making. At various levels of a decision making process, managers face situations where the data available is sparse. This chapter discusses in detail the concept of decision trees- decision nodes, chance nodes and consequences. The decision tree modeling paradigm

provides results based on the expected value of outcome, expected value of profits, expected opportunity loss. It also discusses the formulation and use of a decision matrix.

Chapter 5, “Multi Objective Trade-Off Analysis”, introduces the reader to the analysis of multiple objectives. This chapter will focus on the risk based decision making where trade-offs among all the costs, benefits and risks. Utility theory is also be briefly discussed in this chapter.

Chapter 6, “Defining Uncertainty and Sensitivity Analysis”, introduces students to the use of sensitivity analysis and, through uncertainty taxonomy, to the broader issues that characterize uncertainty in general. It talks about the Uncertainty Sensitivity Index Method (USIM) and its extensions. It covers some basic definitions of sensitivity, responsiveness, stability and irreversibility. The basic differences between optimality and sensitivity are highlighted.

Chapter 7, “Risk Filtering, Ranking, and Management”, introduces a Risk Filtering, Ranking, and a Management (RFRM) method that provides a systematic and quantifiable approach that takes into account a variety of attributes associated with the risks to the system under study. The end goal is to have a sound methodology for ranking the identified risks.

Part II – Advances in Risk Modeling, Assessment, and Management includes chapter 8-18. These chapters will focus on the theory and methodologies that define the state of the art of risk analysis.

Chapter 8 “Risk of Extreme Events and the Fallacy of Expected Value”, introduces the concept of conditional expected value of risk and Partitioned Multi Objective Risk Method (PMRM), which complements and supplements the expected

value of risk. Several examples are used to illustrate the erroneous analysis that is likely to result from the use of conventional expected value as the sole measure of risk.

Chapter 9 “Multi objective Decision-Tree Analysis” extends the single objective decision tree analysis in chapter 4 to incorporate multiple objectives, and the Multiple Objective Decision Tree (MODT) method is explained.

Chapter 10 “Multi objective Risk Impact Analysis Method” extends the modeling, assessment, and management of risk from the static, time-invariant case to the dynamic case. The Multi-Risk Impact Analysis method (MRIAM) is described.

Chapter 13 “Fault Trees” is covered in order to give students an introduction to a tool that is used extensively to evaluate large scale complex engineering systems. Chapters 15, 16, and 17 focus on using many of the tools and techniques for specific settings. Chapter 15 focuses on modeling and analyzing the risks involved with managing complex projects. The news is full of examples of cost overruns, schedule delays and performance deficits for many large scale engineering development projects. Chapter 16 focuses on the use of risk analysis for space missions. Chapter 16 is relevant to the latest interests and concerns associated with modeling, assessing and managing risks due to terrorism. This chapter focuses on issues of risk modeling for infrastructure systems and is relevant to our desire to introduce students to tools and techniques of value to modeling the risks associated with transportation systems and the impact that the failure of these systems could have on other elements of the infrastructure in the country.

5.2 Course Syllabus

The syllabus that was used during the first offering of this course is provided below.

INEG 410V/514 – Risk Analysis

T,Th 8:00 to 9:20

Bell Engineering 2286

Instructor: Dr. Ed Pohl

Office: 4167 Bell Engineering

Telephone: 575 - 6042 (Office)

Office Hours: Tuesday 3:00 - 5:00 pm

442 – 7043 (Home)

Friday 1:00 – 3:00 pm

Email: epohl@uark.edu

Required Textbook: *Risk Modeling, Assessment, and Management (2nd Edition)*, Yacov Y. Haimes, John Wiley & Sons, 2004

Additional References:

Risk Analysis: A Quantitative Guide (2nd Edition), David Vose, John Wiley & Sons, 2000

Risk Analysis in Theory and Practice, Jean-Paul Chavas, Elsevier, 2004

Prerequisites: Engineering Statistics, INEG 3313 or equivalent

Co-requisite: Introduction to Operations Research, INEG 3613

Grading:

			<u>Final Grades</u>
Homework/Participation	100 pts	10%	A \geq 90%
Exams	2 @ 150 pts	30%	B 80 – 89%
Paper Reviews	2 @ 75 pts	15%	C 70 – 79%
Course Project	1 @ 250 pts	25%	D 65 – 69%
Final Exam	1 @ 200 pts	20%	F \leq 64%
Total	1000 pts	100%	

The final exam is comprehensive and will be optional. If you do not take the final exam then I will use the average of your two exams in its place. If you take the final exam and do better than the average of your two exams, I will replace the lowest exam grade with your final exam score. If you do worse than your exam average then your grade will be calculated as shown above.

All graded material will be returned to students during class. Once a graded item has been returned, you have **48 hours to challenge the grade**. To challenge a grade, you must submit a typed description of the grading error (attached to the graded item) to me. Your description must include your name and e-mail address. I will respond to your challenge within 48 hours of its receipt.

Course Objective: Present the engineering student with the fundamentals of modeling risk, analyzing risk, and managing risk in a variety of industrial and government decision making settings. Upon completion of the course, students will have gained an appreciation for the importance of considering risk and uncertainty in their decision making process. Students will understand how to measure risk, quantify

uncertainty, how to build risk models, how to define appropriate distributions from data or from expert opinion, model dependencies, and analyze trade-offs in a multi-objective environment using a variety of tools and techniques. Students who complete this course will be capable of modeling and assessing risks as well as have a basic understanding of how to manage risk and make informed decisions in the face of uncertainty in whatever domain they are operating.

Course Policies:

Communication - Students should check their e-mail on a frequent basis. Class announcements including unexpected cancellations will be e-mailed to you. A course web page is located on UA's WebCT at <http://webct.uark.edu>. You must log onto WebCT and enter your *myWebCT* area. This web page will be used for course-related email and discussion lists, dissemination of materials and access to on-line grades

Homework – Homework problems will be assigned periodically. These problems will be collected at the beginning of the subsequent lecture and assessed. Late homework problems will not be accepted unless a documented emergency prevents you from turning it in on time. The purpose of these assignments is to help you learn the course material. It is okay to discuss assignments with other students. *The written solutions to homework must be your own and not copied from anyone else.*

The following guidelines must be followed in preparing your homework for submission.

1. Show *all work* leading to your conclusions.
2. Define all notation not defined in the problem statement.
3. Provide answers in the context of the problem (with appropriate units).
4. Clearly indicate answers.
5. When necessary, provide written interpretations and conclusions from your data.
6. Work from left to right and from the top down.
7. Clearly indicate the breaks between each part of a problem and the breaks between problems.
8. Write neatly. *Use engineering paper for all handwritten work.*
9. Staple all pages together and *number each page.*

My requirements for assignments are **neatness, completeness and correctness**, and I consider these requirements to be equally important.

Course Project

A course project will be assigned later in the semester. **Graduate students** will do **individual** projects, while **undergraduate students** may work in **teams of two**. The projects will focus on modeling, analyzing and developing a management strategy for a student developed case study that utilizes the tools and techniques from the class on a relevant transportation, security, or infrastructure problem. Details will be provided later in the semester.

Paper Reviews

Each student in the class will be required to review two papers from the scholarly literature that discusses advances in risk analysis or demonstrates specific tools and techniques through the use of examples and case studies. The paper reviews should be 2-3 typed pages that summarize the article and demonstrate your understanding of the material. In addition, each student will develop a 15 minute PowerPoint presentation on their paper. The presentation should include an illustrative example of the tool or technique discussed in the paper. Each student will be given the opportunity to make one presentation during the semester. **Undergraduate students** may work in **teams of two** for each of these assignments or do one paper review and presentation individually.

Inclement Weather - If the University is closed due to inclement weather on the day of a lecture, any assignment (homework or test) scheduled for that day will automatically be re-scheduled for the next lecture.

Academic Honesty - You are expected to read, understand and abide by the university policy on academic honesty. Collaboration is permitted on homework problems. *However, your solutions and write-ups must be your own.*

Software: The software package @Risk will be utilized throughout the semester. Student versions of the software are available on the computers in the Department of Industrial Engineering Faust Laboratory. Students are expected to go through the self paced tutorials on how to use the software. These tutorials are available at the manufacturer’s web site (www.palisade.com/training/risk45.html).

Risk Analysis Tentative Course Outline

The topics to be covered in this course are listed below:

The Art and Science of Systems and Risk Analysis	Chapter 1
Probability Modeling Fundamentals	Notes
Review of Basic Probability Distributions	Notes
Quantitative Risk Analysis Fundamentals	Notes
- Uncertainty and Availability	
- Monte-Carlo Simulation	
- Determining Distributions of Variability from Data	
- Determining Distributions from Experts	
- Building a basic Risk Analysis Model	
- Modeling Dependencies	
Review of basic Optimization Techniques	Appendix A1-A3
The Role of Modeling in the Risk Analysis Process	Chapter 2
Identifying Risks through HHM	Chapter 3
Decision Analysis	Chapter 4
Multi-Objective Trade-Off Analysis	Chapter 5
Uncertainty and Sensitivity Analysis	Chapter 6
Risk Filtering, Ranking, and Management	Chapter 7
Risk of Extreme Events and the Fallacy of Expected Value	Chapter 8
Multi-Objective Decisions	Chapter 9
Statistics of Extremes: Extensions of PMRM	Chapter 11

5.3 Course Project Description

Below is a description of the project that was required of all students taking the course.

Risk Analysis Final Projects

The purpose of this project is to allow students to put into practice some of the risk analysis concepts introduced in the course. The goal is to integrate risk with some of the traditional OR tools on a real world problem. Students will be allowed to work in teams of two on this project. (If you want to work individually come see me) The goal of this effort is for each two person team to perform a **quantitative** risk analysis for a current problem of national, local or personal interest. Utilizing the quantitative risk model, students should propose and model alternatives for mitigating and/or trading off risks for the problem. Teams are encouraged to review appropriate literature in order to adequately define a problem and model its associated risks. Each teams will provide a written report for their project. The report should as a minimum address the following areas:

A.) Problem Definition:

Why is this important?

Who are the stake holders?

What are the risks?

Describe the objective, decision variables, time horizon, etc....

Define an approach for defining the appropriate set of scenarios, associated likelihood, and consequences.

Define potential sources of data for your study

B.) Define a Quantitative Risk Model

Define your model

Explain the tools you utilized (simulation, fault trees, monte-carlo simulation etc..)

Define your data collection process. (how do you get data for your model)

Define any assumptions associated with your model

Analyze the risks with your model(s).

C.) Link your risk model with an Underlying Decision Process

Define the “trade-offs”

Assess the decision utilizing the information from your risk model

Conduct sensitivity analysis on your decision model.

D.) Self-Assessment of your model

Assess the strengths and weaknesses of your model.

What would you do to improve your model?

E.) References and associated Appendices

All teams will present their project results to the class during the final exam period. Each team will have approximately 10-15 minutes for their project.

Suggested Project Areas

1. Vulnerability and Risk assessment of a specific transportation system.

Highway networks

Bridge networks

Urban Transportation System

Subway System

Bus System

Sea lift

People

Freight

Rail System

Airline Transportation

People

Freight

2. Supply Chain Risk Analysis

Identify risks associated with a specific supply chain and model alternatives for making it robust to those risks

Medical Supply chains

Perishable goods

General goods

3. Project Management Risks

Identify a complex project and its associated risks.

Examine cost risk

Examine schedule risk

Analyze alternatives for reducing risks

4. Do a risk and vulnerability analysis for a company/organization/school/ university etc.

Identify natural risks

Risks due to terrorism

Identify alternatives to mitigate risks

Based on models recommend recovery/continuity of operation plan

6 COURSE FEEDBACK

This course was offered for the first time in the spring of 2006. The course had an enrollment of 18 students, 4 undergraduates and 14 graduate students. The course was well received by the students. The overall rating for the course was a 4.6/5.0. The student feedback was positive in general. The students really enjoyed reading the literature and doing a project that required them to put into practice some of the tools and methods discussed during the semester. The students felt that they had achieved the course objectives outlined in the syllabus. Several of the students from this course integrated some the concepts presented in this course into their M.S. thesis and Ph.D. dissertations. I believe the majority of the students acquired new knowledge that they found immediately useful in their research projects. The largest complaint centered on the length and difficulty associated with the two takes home exams administered during the semester. The students also felt like some of the concepts lacked clear explanation in the book and benefited from the use of examples from the literature to help drive home the use and effectiveness of the various tools and techniques presented. The next time the course is offered, we will investigate alternative methods of assessing student performance and understanding that are not so taxing on the students. The materials used in the course, the PowerPoint slides, the exams and home work assignments, as well sample projects and sample paper presentations are available upon request from the author at epohl@uark.edu.

7. REFERENCES

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Kumamoto, Hiromitsu & Ernest Henley, *Probabilistic Risk Assessment and Management for Engineers and Scientists*, IEEE Press, 1996.

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