A new course, *Risk Management of Construction*, is being developed for an MBA/Construction graduate program. The course objective is to prepare construction professionals to identify sources of risk and to develop a rational, analytical approach to responding to that risk. After reviewing the fundamentals of probability and statistics, decision analysis and risk response, the course will cover several sources of construction risk in detail. Causes, modeling methods, and possible responses will be studied for each risk source. These methods will be applied in case studies of recent construction projects and in an independent study assignment.

**Key Words:** Risk Management, Construction, Probability, Statistics, Risk Response, Decision Analysis

## Introduction

All construction projects involve risk. A company preparing a bid on a project should first identify sources of risk on the project then adjust the bid price or place qualifications on the bid (if possible) to address the potential cost impact of risk on the project. If this risk analysis employs probability concepts, the cost impact will be a function of both the cost and the likelihood of an adverse situation. Constructors that employ these methods accurately will be able to safely submit more competitive bids. With a consistent, probability-based approach the constructor will lose money on some operations due to randomly occurring adverse conditions, but these losses will be made up on other projects. Risk management in construction is frequently based solely on intuition derived from the constructor's experience. A more scientific, quantitative approach would be more accurate and effective.

A new course entitled *Risk Management of Construction* is being developed for an MBA/Construction graduate program (Kay et al. 2000). The course will review basic concepts in probability and statistics and their application in decision/risk analysis (Korn, 1995). Four options for risk response – retention, reduction, transfer and avoidance – will be introduced (Flanagan and Norman, 1993) and quantitative methods for evaluating each option will be...
developed. Several common sources of construction risk will then be studied in detail. Discussion will focus on the causes of each source, methods to quantify and model the risk, procedures to reduce the level of risk, and approaches to assign/transfer the risk. The course concludes with case studies of construction projects where some level of risk management was used. The risk management methods will be reviewed and alternate approaches applied and studied. Each student will be required to independently study the application of risk management on a current or recent local construction project and prepare recommendations for improvements to those procedures.

Objectives

The objectives of this course are to insure that students develop an appreciation for the sources of risk in construction and are prepared to address these potential problems. Analytical approaches will be developed as an alternative to the more common practice of arbitrarily adding a premium to the bid price based on experience or "intuition" to account for risk. Students will be prepared to identify several potential strategies for addressing a source of risk and then evaluate which should be pursued for the lowest expected cost. Concepts of utility value may then be applied to determine the final strategy.

Fundamentals

Half of the course will be devoted to learning the fundamentals of probability and statistics, decision analysis and risk response to provide a foundation for analyzing sources of risk and developing response strategies for construction-specific problems in the second half of the course. Probabilistic and statistical methods for characterizing uncertainties will be covered along with Bayesian approaches for estimating probabilities with limited data. These models will then be used in decision trees to calculate the expected monetary and/or utility value of various decisions. Various risk response options such as adding a risk premium to a fixed-price bid and transferring risk through insurance or contract provisions will then be discussed. Monte Carlo simulation methods will be introduced for estimating probabilities in complex situations (Ang and Tang, 1984)

Probability and Statistics

The first two weeks of the course will be devoted to a review of the fundamental concepts of probability and statistics. Although the prerequisites do not include a probability and statistics course, most students at this level should have had some experience in these areas. The review will provide a framework for additional self-directed study for students with deficiencies. The course will only require an understanding of basic concepts. The objective of the course is to develop methods to apply these principles to construction risk so the emphasis will be on
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Fundamental concepts from set theory will be reviewed to establish the definition of union and intersection of events. These are applied with mathematical definitions to derive theorems to calculate probabilities of events given their levels of interdependence. Applications of the theorem of total probability and Bayes' theorem will then be presented. The development of random variables to model random phenomena will be reviewed and the use of the binomial and normal distributions presented as useful examples of discrete and continuous random variables.

Concepts of sample statistics and measures of the quality of these estimates of actual population properties will be presented along with approaches for estimating statistical properties with minimal data. Regression analysis techniques and the interpretation of those results will be used to determine the relationship between multiple variables. Typical quality assurance/quality control methods will be discussed. Methods to evaluate the probability of passing specified quality requirements will be derived and used to determine the target level of quality required to minimize the expected net cost of acceptance.

**Decision Analysis**

Once a source of risk is identified, the possible responses must be analyzed to determine the best course of action. The decision criteria may be to select the option that presents the least *expected* cost or to include other values of the decision maker in a calculation to maximize the utility value (Lockhart and Roberds, 1996). For example, the decision to buy an insurance policy will never produce the least expected cost if the actuarial scientists at the insurance company are competent; however, the decision maker's desire to avoid a possible catastrophic loss will frequently give the decision to purchase insurance the highest utility value.

Methods to develop decision trees will be studied to provide an organized approach to evaluate the proposed courses of action. The Bayesian approach will be applied to update the probability estimates used in the decision trees given additional information. This method will then be used to evaluate the value of information in order to determine whether the cost of improving probability estimates (and, thereby, the decision) through additional analysis can be justified (Lifson and Shaifer, 1982).

**Risk Response**

Four principal risk response options will be reviewed in the course -- retention, reduction, transfer and avoidance. It will usually be more economical to retain repetitive risks with small consequences. As long as the company can cover the cost of an adverse outcome on one project, it will be balanced by other projects with favorable outcomes. Procedures to calculate a risk premium to be added to the price of a job based on expected cost will be developed. For example, when bidding a job requiring liquidated damages for late completion, the bid would be
increased as a function of the possible levels of liquidated damages multiplied by the probability of the corresponding delays. A bid increased by the maximum probable liquidated damages would rarely be successful. If a company adds a probability-based risk premium to multiple jobs, they will win some and lose some, but the loss from one late job should be offset by the premiums charged on projects that are completed on time.

Many risks can be reduced through better management and training of the construction staff. Risk reduction may require additional resources, and this expense must be justified by reductions in the expected cost. For example, robots can be used to minimize the risk of worker's compensation claims, but with current technology the cost of the robots would probably be much greater than the cost of potential injury in all but the most dangerous situations, so this approach would generally not be economically justified. Additional project monitoring and testing can also be employed to reduce the risk of undetected problems that may lead to expensive remediation in the future; however, these costs must also be justified based on the probability of a major, undetected problem.

Risk can be transferred to other entities through insurance or contractual requirements. In a professionally run project, all parties should be aware of the risks that are assigned to them and of the possible consequences. Ideally, the net cost of risk will be minimized when risk is assigned to the party that has the greatest control over that aspect of the project. Risk may be avoided by staying out of the construction business, but the students in the course probably don't consider that to be an option. Companies must be prepared to choose not to bid on a project in which the risks are greater than the potential reward. The risk response section of the course will focus on methods to evaluate the costs of various risk response options and select those that are economically justified.

Sources of Risk

The second half of the course will focus on applying risk management concepts to construction applications. Several common sources of risk will be studied in detail to identify the causes, modeling methods, and risk reduction and transfer procedures for each source.

Schedule

When projects are not completed on schedule, the constructor usually incurs additional costs and must continue to commit resources that may be required on other jobs. Schedule risks will be evaluated by modeling the duration of each task as a random variable in a typical CPM schedule network. Both discrete and continuous representations will be discussed and Monte Carlo simulation methods used to evaluate the probability of various completion times (Ang and Tang, 1984). The duration of multiple tasks may be correlated if they are caused by a common source (e.g. weather or labor problems). Methods to identify and account for this correlation and to derive the duration random variable from probabilistic models of these causes will be
studied. Some schedule risk may be transferred to subcontractors. "Crashing" critical tasks through the application of additional resources or overtime can also make up schedule delays. These approaches usually increase cost, so procedures to compare the cost of reducing project duration to the cost of delays will be developed (Raftery, 1994).

Cost

Most categories of construction risks are ultimately expressed in terms of cost, but uncertainty in direct cost items such as labor, equipment and material are included as a separate classification. In times of high inflation or impending labor negotiations, unit costs will be dependent upon the project start date and will be less certain on long duration projects. Standard engineering economy methods to include inflation in cost estimating will be reviewed (Sullivan, et al., 2000). Procedures to include uncertainty in these calculations and to estimate inflation from various construction cost indexes will be presented.

Quality

When a construction job does not meet the quality standards required by the contract, the constructor must correct the problem to the owner's satisfaction. Quality problems can be remedied most economically when they are discovered early; however, quality control and inspection are expensive so an appropriate level of effort must be determined. The course will focus on two examples. The first will be to determine the level of effort that should be expended in a soil compaction operation to minimize the net expected cost. The probability and cost of failing the initial customer inspection will be included in the analysis. In the second example, a low 7-day concrete specimen strength is reported on a project. The possible responses will be developed and analyzed.

Technical

Complex projects present serious challenges to the constructor. Potential difficulties may be overlooked in the bidding process and lead to schedule and budget problems on the project. Technical challenges must be identified during bidding and consideration given to procure specialized equipment or hire qualified people to perform or supervise the work. When new materials or processes are being used, worker training may be required. Sources of technical risk will be discussed in the course in order to improve the ability of students to identify these areas.

Unknown Conditions

Good design documentation should provide adequate information about job-site conditions; however, additional interpretation may be required especially where subsurface conditions are being estimated from a limited number of borings.
Projects constructed in other countries present additional sources of uncertainty and risk. Cost uncertainties are exacerbated by exchange rate fluctuations. The skill of the available workforce will affect quality and productivity, and political uncertainties and local business customs and construction laws can present additional challenges (Bodapati and Kay, 1998). Obviously, an international project should not be pursued without consulting with people familiar with construction conditions in that country. Methods to account for currency risk and insurance options for international construction will be discussed in the class.

Unexpected environmental conditions on a construction site will influence schedule and cost. For example, the discovery of underground storage tanks in previously developed areas is a common occurrence (Edwards and Bodapati, 2000). The course will cover some of the legal responsibilities of the owner and constructor under current environmental law and discuss the value of pre-construction environmental site assessment to reduce project risk.

Construction is a dangerous occupation. Injuries on the job cause short-term disruptions but can also affect the company’s long-term success due to increases in workers compensation rates, government fines, and other potential litigation. Many decisions affecting construction safety are prescribed by OSHA regulations. However, the level of attention given to safety by a constructor and the enthusiasm with which they enforce regulations will influence the risk of injury on the job site. The costs of safety programs and their effectiveness at reducing risk and improving/degrading job site efficiency will be evaluated.

The formal course instruction will conclude with case studies of risk management applied to construction projects. The instructor will interview local contractors to identify risks that were encountered on recent projects and the approaches used to address those risks. Methods developed in the course will then be applied to these situations to study alternative approaches. In the course of preparing the case studies, the instructor will also identify topics for the students to pursue for their independent study reports.

Students will present their independent study reports in the final class session. Each student will identify an appropriate construction project, interview the project supervisors, and prepare a
quantitative analysis of project risks. The report will include recommendations for the approaches to address the risk. Students will be required to submit a concise written report in addition to the oral report.

**Conclusions**

Risk is inherent in construction operations. Many constructors say that they don't need to visit to casinos for excitement because they are gambling every time they submit a bid. In the casinos, the house sets the odds, and all regular gamblers will eventually end up losing. The construction professional, on the other hand, can take action to influence the probability of success or failure and can adjust bids on projects to insure that the odds are in their favor. By pursuing a rational approach instead of being overly conservative, a constructor will win more business and, despite some losses, come out ahead in the long run. This Risk Management of Construction course will provide construction professionals with the analytical tools to address construction risk rationally.

**References**


