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INSTITUTE

MANAGEMENT OF PROJECT RISKS AND UNCERTAINTIES

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The Construction Industry Institute
The University of Texas at Austin
3208 Red River
Suite 300
Austin, Texas 78705-2650
(512) 471-4319

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Prepared by
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INTRODUCTION

"The only sure things in life are death and taxes." While not questioning those two, it would seem that another factor is equally sure-uncertainty. Whether speaking of human or business life, each is subject to uncertainties, many of which involve risks which continually challenge it. Risks threaten both physical and economic well-being. Daily newspaper and television reports are filled with accounts of accidents and disasters, criminal and terrorist activity, political upheavals and economic collapses. The occurrence of a tragedy means that an everyday risk has been converted from threat to event in some location with injury, death, property loss and economic hardship befalling the victims. We also know that next week those or other tragedies could hit any of us so we. buy insurance, establish savings programs, dig a tornado shelter or otherwise protect ourselves should such tragedy strike. And, for a life to survive and prosper, it must continually face and manage these uncertainties.

Uncertainties that have only a loss potential tend to command most of our attention. Yet some uncertainties have the potential for gain. For example, we know that investing in the stock market has the potential for gains as well as loss. Management of uncertainty must consider the potential in both directions.

This report is an introduction to risk management and dealing with uncertainty, particularly as it applies to construction contractors. Specifically it will:

- Provide a basic introduction to risk management.
- Introduce typical methods of identifying risks.
- Identify common risk measurement methods.
- Provide guidance for risk control.
- Provide guidance for contingency account management.

This report is based in part upon "Risk Management in Capital Projects," a CII source document. That report deals with management of risk as applied to owners, construction managers and constructors involved in the total engineering, procurement and construction of a capital construction project. This report focuses more on management of risk for a construction contractor; however, most of the recommendations presented here are equally applicable to owners, designers and subcontractors.

The term "risk management" often is applied to the duties of the staff section within a company that handles insurance matters for the company. As will be emphasized in subsequent chapters of this document, however, risk management includes considerably more than insurance. Thus, as used in this document, the term "risk management" encompasses the full spectrum of activities associated with identification, measurement and control of risk.

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RISK BASICS

Risk Definitions and Classifications

Various authorities define risk in different ways. Webster speaks of it in terms of a potential for loss or injury-in other words, if there is a risk, the best one can hope for is no loss or injury. Risk obviously involves uncertainty. If the outcome were totally predictable, there would be no risk. Risk usually involves variability in both frequency and severity-the outcome can occur within a range.

Most experts define risk in terms of its parent-uncertainty. Uncertainty is simply the set of all potential outcomes, both favorable (if any) and unfavorable (if any). Those outcomes which are unfavorable represent risk, whereas those which are favorable represent opportunity. Thus, uncertainty can give birth to either, or both, risk and opportunity.

Risk is also defined as the probability that an unfavorable outcome will occur. Similarly, opportunity is defined as the probability that a favorable outcome will occur.

A popular way to catalog uncertainties (and thus risks and opportunities) is in terms of *known, known unknown* and *unknown unknown* situations or conditions. Using examples in our personal lives, an individual playing the stock market (which has both risk and opportunity) or operating a power saw (which has only risk) is aware of a range of potential outcomes inherent in both activities-these situations are *knowns.* A *known unknown* is an acknowledged situation that could affect the activity, but its potential for occurrence is not immediate nor would one normally expect it in the course of the activity. A disease such as cancer is an example-you know it exists in our society and could strike you, but you do not see a direct threat to your life until it is diagnosed. You see the potential for loss of your job, a serious auto accident or a lawsuit by someone injured on your property as other *known unknowns.* The *unknown unknowns* are the situations we have not even heard about or can not imagine; yet, we realize that some unforeseen risk can materialize to threaten us. AIDS was an *unknown unknown* risk until recently.

Uncertainties, and therefore risks and opportunities, can also be cataloged by source. *Technical uncertainties* relate to the technological aspects of the project. An owner building a facility that incorporates a new process must balance the potential risks against the potential opportunities. The same applies to a contractor attempting an innovative construction procedure. *Contractual risks* are found in any contractual agreement. The contract language is not always clear, some key issues may not be covered in the contract and the all-toocommon adversarial situation between owner and contractor can lead to many problems. *Financial risk* is the third source. This risk is primarily with the owner on a cost-reimbursable project and primarily with the contractor on a fixed-price project.

Uncertainty and the Project Cost Estimate

In estimating the total cost of a project, a phenomenal number of potential outcomes exists, ranging from the best potential underrun to the worst potential overrun. All potential outcomes which are unfavorable (i.e., cost overruns) represent risk, whereas those which are favorable (i.e., cost underruns) represent opportunity. In this same context, if there is a 60 percent chance that a cost overrun will occur, then the probability of 60 percent is referred to as the risk. Conversely, the probability of 40 percent that a cost underrun will occur is referred to as the opportunity.

If, as is often the case, all the potential outcomes are numerical, they can be depicted as a range. For example, consider a project in which the target estimate for excavation is $100,000. This target estimate is one of a large number of potential excavation cost outcomes. One of those potential outcomes relates to everything going right-the best weather along with the best soil conditions and the best labor productivity (a highly unlikely scenario to be sure, but one which must be considered). The cost associated with this potential outcome might be $80,000. Another potential outcome relates to everything going wrong-the worst weather along with the worst soil conditions and the worst labor productivity. The cost associated with that potential outcome might be $130,000. Thus, the set of all potential outcomes is captured in a range with a lowest estimate of $80,000 and highest estimate of $130,000. Considering only whole dollar figures, the uncertainty related to excavation cost is a set of 50,001 potential outcomes (30,000 unfavorable and 20,001 favorable).

The target estimate separates the range into two segments. The segment above the target contains those potential outcomes which are unfavorable (i.e., cost overruns of increasing magnitude from the target to the highest estimate). This segment of the range is the risk. The segment below the target estimate contains those potential outcomes which are favorable (i.e., cost underruns of increasing magnitude from the target to the lowest estimate). This segment of the range is opportunity.

Degree of Risk

What are the characteristics of any risk element that determine its importance to the decision maker? These are some:

The potential frequency of loss

The amount of information available to define its potential

The potential severity of loss

The manageability of the risk

The vividness of the consequences

The potential publicity should the loss occur

The ability to measure the consequences of loss

One more element might be added to the above list-whose money is it? individuals probably tend to be more reckless in managing assets belonging to other parties than they would their own.

It appears that severity of potential loss is the one factor that attracts the attention of decisionmakers more than any other. Individuals are willing to accept small (even frequent) losses, but are averse to a risk which has high stakes. That is why catastrophic loss insurance and deductible insurance policies are so popular.

Risk Management

A total risk management program has three stages. In this chapter they are introduced as they apply to an individual. In subsequent chapters they will be applied to a construction project.

Risk *identification* is the first stage. This is simply the cataloging of risks that may befall the individual in question. This is compiled based *on* general knowledge and experience combined with a "what can happen" analysis of the future.

The second stage is *measurement* or evaluation of identified risks in terms of potential cost should the risk become an event. When dealing with personal assets, such as a home or car, it is easy to establish a potential loss figure based on replacement value. An infinite number of loss scenarios exists, however, for a vehicle and its occupants and the probability of each is a function of many factors.

Risk control, the third stage, is achieved in various ways, one of the better known actions being the purchase of *insurance. Risk avoidance* is another technique; for example, you can avoid the liability risks of car ownership by not owning one. If you own a car, you can *reduce* risks by less frequent use of the car or *share* risks by carpooling. You can *transfer* those risks by traveling on public transportation only. Again, if you own a car, you can insure yourself totally or you can *accept risk* by not insuring at all or accept part of the risk by buying only partial coverage or deductible insurance. You can save for that "rainy day" by establishing a savings program *(contingency funds).* Finally, you can *contain risk* by careful driving, wearing seat belts and having regular safety inspections. In summary, risk control includes risk avoidance, risk reduction, risk sharing, risk transfer, insurance, risk acceptance by establishment of contingency accounts, risk acceptance without any contingency and risk containment.

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RISK IDENTIFICATION FOR CONSTRUCTION

Overview

Certainly all in the construction profession will agree that risks are found in every project. Safety risks are inherent in construction activity; business risks are associated with any venture involving contracts, multiple agencies, time and money; performance risks are associated with producing goods and services with a constantly changing human work force operating under variable weather conditions and the uncertainties of materials and equipment deliveries; and liability risks threaten every business in our litigious society. We also are painfully aware of examples where failure to manage those risks has resulted in significant losses to the contractor.

If we are to manage the risks inherent in a project, we must first identify those risks. We will find that construction projects, like individuals, are subject to risks which can result from *known, known unknown,* and *unknown unknown* conditions.

Identification Responsibility

Too often the risk identification function is performed by one or more project personnel. Risk identification is the responsibility of the entire project team. Competent risk identification relies on historical information, formalized checklists of risks and the collective experience of the project personnel. The project team should have several opportunities to brainstorm the entire project and discuss the risk items identified by the individual participants. This will help insure that all risks have been identified, defined and interrelated.

Risks from Known Conditions or Situations

The most common risks in the project to identify are those which come from known conditions (knowns). These risks are typically those which must be explicitly or implicitly accounted for in the estimate. In general they involve a continuous range of outcome, have a relatively high frequency and are individually of relatively low severity (at least not catastrophic).

The contract documents themselves are one of the first places to look for these. They define the products and services to be provided, the time requirements and the payment provisions, and establish a variety of administrative requirements that the contractor must accept if the contract is awarded. These contract terms must be reviewed by a battery of specialists. The legal or contracting personnel will check to insure that the contract terms are generally fair and equitable, that vital protective clauses are present, that no burdensome clauses exist and that no risks have been assigned that properly belong to others. Project management personnel must check all time requirements and determine that they are achievable. Of course, they must also identify unusual risks associated with the type of work involved. Project controls, materials management, quality management and other specialists must check all requirements in their respective areas-are they clear or are they vague, or are they subject to interpretation and a potential source of disagreement between owner and contractor? Estimators must identify quantities of work. Their work is always subject to error. If the plans are incomplete or of poor quality, there can be considerable error. On a fixed-price project, an unfavorable quantity variance will be a loss. Subsurface conditions must always be considered. Are subsurface data complete and reliable? Who has responsibility for unforeseen subsurface conditions? The results of these reviews provide a catalog of requirements and risk conditions which must be evaluated.

The area survey conducted as part of preconstruction planning will identify other risks coming from *knowns.* Perhaps the site is congested, transportation access may be limited, the nearby communities may be too small to absorb and support the anticipated project population or competing projects in the area may limit labor availability. Detailed checklists should be used during these surveys to minimize the potential for overlooking some risk item.

Labor productivity is always a *known* derived risk on a project. Using a combination of historical experience and information generated during the area survey, productivity judgments must be made for all work. The probability of these judgments being correct is essentially zero; at best, estimators can reasonably predict that productivities will occur within a range.

Finally the project team as a group should brainstorm the entire project and list risk items identified by the individual participants in their review of the project. This will help insure that all risks have been identified, defined and interrelated.

Risks from Known-Unknown Situations or Conditions

Known-unknown conditions *(known-unknowns)* which include risk exposure are neither explicit nor normally expected, but are foreseeable and possible. In general, they tend to be discrete events, yet have a low frequency of occurrence and a high severity of impact when they do occur. They are best identified through review of historical reports on comparable past projects. Extreme bad weather (e.g., tornado, hurricane, floods), unusual difficulty with a client, extreme adverse labor activity, sudden labor shortages due to new and competing work activity in the project area, commodity shortages due to embargos and regulatory interventions are representative known-unknowns that have affected other projects. A checklist of potential known-unknowns will assist greatly in developing the list for the project at hand.

Risks from Unknown-Unknown Situations or Conditions

Unknown-unknown situations cannot be identified in advance; their potential can only be acknowledged. Again, historical records may provide some guidance on the extent that *unknown-unknowns* have had on past projects. Essentially, these must be grouped together as a single risk line item that has potential catastrophic effects, but a low probability of occurrence.

The Risk Checklist

In the identification of risks, a checklist will always prove helpful. Obviously, the checklist for an owner will differ from that of a contractor or engineer. For the sake of providing an example, the listing below is for a contractor.

- Reputation-potential for unfavorable exposure

- Project Execution Strategy Employed
  - General contract
  - Construction Management-multiple prime
  - Owner-multiple prime

- Project Size
  - Physical area
  - Population-total and individual craft

- Type Contract
  - Lump-sum
  - Unit-price
  - Guaranteed maximum
  - Reimbursable

- Unfavorable Contract Clauses
  - Differing site conditions
  - Hold-harmless
  - No damage for delay
  - No relief for force *majeure losses*
  - Not responsible for quantity variations

- Area Factors
  - Geography/geology/altitude
  - Area economic conditions
  - Government stability & sophistication
  - Police, fire and medical support
  - Local population attitude and stability
  - Transportation network
  - Communications
  - Other support infrastructure (housing, etc.)

Site Factors
- Topography/drainage/trafficability
- Access/egress
- Congestion
- Adjacent operations
- Hazards-safety and health
- Location and adequacy of construction support facilities/areas
- Availability of utilities
- Security

Weather
- Normal weather patterns
- Potential for extremes

Monetary
- Bidding costs vs. potential for award
- Escalation
- Exchange rates
- Area cost indices
- Payment floats
- Retention
- Unbudgeted premium time
- Overhead costs
- Contractual penalties (liquidated damages, etc.)
- Regulatory penalties (OSHA, EPA, etc.)
- Bonuses & shared savings

Ability to Perform
- Familiarity with type work
- Availability and qualifications of key personnel
- Knowledge of area
- Completeness of design
- Quality of design
- Timeliness of design
- Complexity, constructability of design
- Requirements for new technology
- Competing activity on site
- Availability of access to work when required
- Need for work or fire permits

Time Factors
- Deadlines and milestones
- Available normal work days
- Potential for stoppages by other parties or situations

Regulatory Factors
- Permits-potential for delays or rejection
- Environmental-potential for spills, emission, other violations

Labor Factors
- Availability
- Skill levels
- Work ethic/area productivity standards
- Wage scales
- Potential for adverse activity
- Substance abuse in labor population

Client Factors
- Financial stability
- Construction management sophistication
- Interferences
- Quality expectations
- Interpretation of contract
- Ability/willingness to meet obligations
- Change management policies

Contractor-Furnished Materials Factors
- Quantity variations
- Quality
- Price
- Availability
- Delivery uncertainties
- Contract-imposed procurement limitations
- Potential for waste in use
- Potential for loss (theft, vandalism, damage)

Construction Equipment Factors
- Availability
- cost
- Loss or damage

Subcontractor/Vendor Factors
- Technica! qualifications
- Financial stability
- Timeliness/reliability
- Bondability
- Minority, women, disadvantaged business and small business enterprise requirements

Care and Custody Exposure
- Constructed facilities
- Storage of materials/equipment furnished by others

Special Exposures
- Insurance deductibles
- Client claims
- Third party litigation
- Warranties & guaranties
- Permitting requirements

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RISK MEASUREMENT IN CONSTRUCTION

Overview

Once risks have been identified, the next goal is to somehow associate a potential loss with each risk. That loss is expressed as a time, resource or a monetary loss. These problems make the process difficult:

For each individual risk, there is usually a broad range of potential loss.

Some risks, particularly some of the *known unknowns* and all *unknown unknowns* defy definition in terms of potential for loss.

Many risks are involved in the project. The number of combinations in which these risks can create losses is infinite.

How then can the risk analyst get a handle on the problem? Research on the subject of uncertainty shows an almost universal tendency for people to underestimate uncertainty and overestimate the precision of their own knowledge and judgment. Thus, "gut feel," single-number judgments in estimating potential losses can be dangerous, particularly when evaluating the combined effect of a number of variable items. Research also has shown that one can extend the confidence level by using simulations that eliminate the biases of single-figure subjective judgments.

Methods

A number of methods are available for handling risk and uncertainty. These may be cataloged as follows:

Traditional- the use of allowances based on past experience. For example, an allowance of 5 percent may be included for bulk material quantity growth, another percentage for possible wage increases or an across-the-board markup given to the entire estimated cost of the project to account for all variables. This is basically an experienced judgment approach based on previous experience with comparable work.

Simulation- methods which use the power of the computer to predict the possible range of outcomes for the project. Usually known as Monte Carlo methods, simulation techniques are the most common measurement technique after the traditional method.

Analytic- the use of the mathematics of probability to assess and combine the effects of the individual risk events into an overall measure of risk.

Discrete Event- Typical approaches use decision trees, influence diagrams and utility theory. These techniques are especially appropriate for analysis of known unknown risks.

A complete description of these techniques cannot be accomplished in this report. Readers are encouraged to obtain the source document for more information. Only the Monte Carlo technique will be described because it is experiencing increasing favor within the industry for risk measurement. Several commercial risk management software programs are based on this technique.

Monte Carlo Technique

The Monte Carlo technique uses a statistical model that may be applied to events where the outcome of each event can occur over a range represented by a frequency curve. Figure 1 is an example of such a curve for work-hours required to complete a typical task, the data representing a large number of possibilities. The Monte Carlo technique is useful for evaluating the combined potential of multiple, independent variables such as this one.

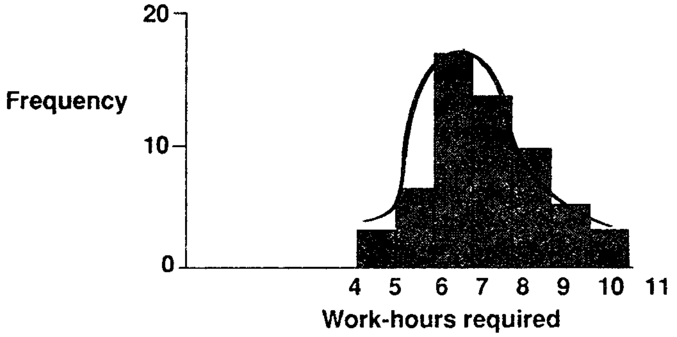

Figure 1. Frequency Curve

Identifying the Critical Cost Elements

The Monte Carlo technique is applied in the following manner. First, the critical cost elements in the project are identified. The typical project has numerous cost elements, but Pareto's Law (the law of "the significant few and the insignificant many") tells us that only a few are critical. It is this phenomenon that both causes the problem and allows us to solve it. Since only a few critical elements exists, it is quite possible that a majority of them will go in the wrong direction and thus lead to a cost overrun on the project. On the other hand, their small number allows us to concentrate on them to better understand how the project is likely to unfold. Which cost elements, then, are critical?

We first must decide what is critical as far as the bottom line cost is concerned. Specifically, what maximum variation in bottom line cost, caused by a variation in a *single* cost element, are we willing to tolerate? One rule-of-thumb* places this threshold in the neighborhood of 0.5 percent in conceptual cost estimates and 0.2 percent in detailed cost estimates. Using this rule, if the target bottom line cost of a project in a conceptual cost estimate is $1,000,000, then the threshold is $5,000.

The critical cost elements in the project now can be identified. Specifically, a critical cost element is one whose value can *vary* from its target estimate, *either* favorably or unfavorably, by such a magnitude that the bottom line cost of the project would change by an amount greater than the threshold. Thus, in the previous example of a $1,000,000 conceptual cost estimate, any cost element in the project which can change the bottom line cost, either favorably or unfavorably, by more than $5,000 is classified as a critical cost element.

This rule-of-thumb has been successfully applied in thousands of projects of all types ranging in size from $100,000 to $12 billion. Well over 90 percent of those projects had fewer than thirty critical cost elements.

It is important to note that the deciding factor in determining criticality is the potential for variation, not the magnitude, of a cost element. For example, a cost element may account for a large portion of the bottom line cost of the project, but may have little or no potential for variation. In other words, the actual value of the element cannot be sufficiently different than its target, either favorably or unfavorably, to produce a bottom line change which is greater than the threshold. Such an element is noncritical. On the other hand, another cost element (at its target) may account for a small portion of the bottom line but can vary from its target, either favorably or unfavorably, by such a degree that the bottom line change would be greater than the threshold. A cost element such as this is critical.

Potentially critical cost elements include liquidated damages for delay in completion and/or incentives for early completion, uninsured losses, costs of various major labor-intensive work activities, costs of major bulk commodities and overhead items.

Variability Ranges for the Critical Cost Elements

Once the critical cost elements are identified, the potential variability of each must be determined. This simply means that in addition to its target estimate, each critical element is assessed in terms of its lowest and highest potential values. These lowest and highest estimates are far enough from the target estimate such that there is less than a 1 percent chance that the actual will be lower than the lowest estimate and less than a 1 percent chance that it will be higher than the highest estimate.

* The criterion suggested here is that proposed in the article, "Range Estimating-Measuring Uncertainty and Reasoning with Risk," Michael W. Curran, *Cost Engineering,* Volume 3, Number 3, March 1989.

For example, assume that a critical cost element has a target estimate of $100,000. The project planners believe there is less than a 1 percent chance the actual cost will be lower than $80,000. They also believe there is less than a 1 percent chance the actual cost will be higher than $130,000.

Handling the Noncritical Cost Elements

Once the critical cost elements in a given category (labor, for example) have been identified, the sum of their target estimates is subtracted from the total target estimate for the category. This difference, of course, is the sum of the target estimates of the noncritical cost elements in that category. In other words, the sum of the target estimates of the noncritical cost elements is “backed out” of the traditional estimate. The noncritical cost elements in that category are “frozen” at this figure for the Monte Carlo simulation.

Grouping all noncritical cost elements of a category into one figure is justified. Remembering that not one of these elements can vary the bottom line by more than the threshold value and that there are numerous noncritical cost elements, their behavior *as a group* is predictable. There is a cancelling effect-for each noncritical cost element in that category that overruns we can expect another noncritical cost element in that category to underrun such that the total dollars of overrun is essentially offset by the total dollars of underrun. In other words, there is a “wash” in the noncritical cost elements in that category. Such is not the case, however, if there is bias in the traditional estimate. There will be no cancelling effect if most of the noncritical cost elements’ targets are optimistic or if most of them are pessimistic. In such cases, the bias should be compensated for by freezing the total of the noncritical cost elements at a value either higher or lower than their collective target estimate for the category. Or, if sufficient uncertainty exists regarding the degree of the bias, the *total* cost of the noncritical cost elements for that category should be assessed with a range.

Once all critical cost elements are ranged and noncritical cost elements frozen or ranged as a group, the Monte Carlo method is employed, typically on a computer. This results in a frequency distribution curve for the project similar to that for the individual work item shown in Figure 1. From this is developed a *cumulative probability* curve, also called the *Overrun Profile.* It displays potential project cost versus probability of that cost being overrun. Usually 1,000 or more simulations are performed to develop the overrun profile.

Figure 2 is a simple example of an overrun profile as might be generated using the Monte Carlo technique. This profile is an excellent tool for project managers to use in evaluating exposure. For example, it can be seen that there is about a 20 percent probability that the project cost will exceed $21 million. The 50 percent point is about $19.75 million.

In each of the methods described, the analysts are required to establish at least the high, low and target estimate for each critical cost element. In the more sophisticated Monte Carlo methods, the analysts also either select the probability of the target estimate not being exceeded, or more completely define the variation. Subjective judgments are required to establish these figures. It is better if these are arrived at through group brainstorming rather than leaving the process to a single individual as this will broaden the base of experience and knowledge applied to the process and eliminate individual biases.

Not all cost risk items are included in the ranging process, or at least their full potential cost is not considered. For example, many of the risks are insurable and protection is best provided with insurance. Usually, this insurance has a deductible portion so range values are found by multiplying the deductible amount by the estimated high, low and target frequency of occurrence. Of course, the cost of the insurance becomes a fixed-cost item in the contract.

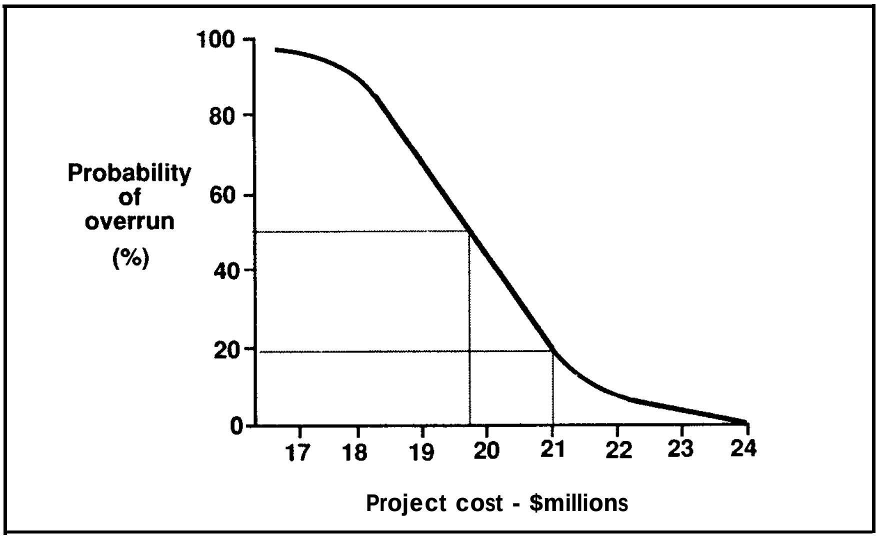

Figure 2. Overrun Profile

Selecting Method

Monte Carlo methods comprise only one of several techniques available to accomplish risk analysis. Selection of an appropriate technique for a given project is a function of several factors. Project characteristics which affect the selection of a risk measurement technique are:

how seriously the risk is viewed by management

the complexity of the risky environment

the expertise which is available to perform the risk analysis

Also, when selecting a risk measurement technique, one must consider that some techniques require more input data. Some give more appropriate output. Some are better at modeling highly complex risks and others are more appropriate for simple circumstances. On the basis of actual usage, however, the traditional and simulation methods have become the most accepted.

Schedule Risk

Time as well as cost is subject to variability, which should be considered within the risk management program of the project. As with cost, both the traditional and simulation approaches can be applied to schedule risk. A number of commercial software programs are available for the simulation approach; of course, the traditional approach uses a brainstorming approach for determining the potential for overrun of the schedule.

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RISK CONTROL FOR CONSTRUCTION

Overview

Once risks have been identified and measured, management moves into the risk control stage. Actions in this stage fall into two broad categories-advanced planning actions and risk containment actions. The advanced planning actions are designed to place risk exposure within controllable limits. The in-process actions are designed to keep actual losses below target and approaching zero, or even to generate additional profit.

Advance Planning Actions

During the pre-bid phase, the contractor seeks to identify all potential cost items in the contract so that the contract can be realistically priced. For work items, the contractor will envision all potential methods for accomplishing the work with a view to finding the most cost-effective approach. For risk items, the objective is also one of cost-effectiveness-what can be done to minimize or best control the exposure? A number of actions are possible in advance of bid submission.

Risk Avoidance. An option always available to the contractor is to avoid all risks by dropping out of competition for the project. Such is a wise choice when loss potential clearly outweighs the profit potential. Obviously, loss potential exists on every fixed-price contract so it is a matter of degree. If major risks involved are the type which the contractor can truly control through prudent management and if prudent management can increase the profit, the contractor will surely decide to proceed. On the other hand, if high probability risks are beyond contractor control (such as unforeseen subsurface conditions for which the owner disclaims responsibility; or unjustified hold-harmless clauses that transfer responsibility for owner or engineer mistakes to the contractor), the decision should be otherwise.

Another example of avoiding risk is to use only proven technologies and practices. The flip side of this, however, may be a lost opportunity for greater profit through a new technique.

Risk Sharing. A joint venture arrangement is a classic way to share risk. Another example is a target cost/work-hour contract, where risk is usually shared through a formula that splits overruns and underruns between owner and contractor. The partnering concept includes risk sharing. Still another example is the use of worker incentive programs.

Risk Reduction. Through study of particularly risky elements it may be possible to find an alternate which carries with it less loss potential. For example, a constructability analysis may replace planned field assembly of some components with shop prefabrication to avoid potential weather delays.

Risk Transfer. A second option is to *transfer* the risks. Certain risky elements of the contract may be handled best by subcontractors. Or if the request for proposal allows, the contractor can include rejection of some owner-assigned risk or can request revised contract wording as an exception in the proposal.

Insurance. The potential losses associated with many risks will be insured through Workers' Compensation, Bodily Injury and Property Damage Liability, Builders' Risk and other policies. Workers' Compensation insurance is a statutory type of insurance and contains no options as to coverage required, although in some states and under some conditions the contractor can self-insure. When self-insuring, this becomes a major risk item; when insured through a commercial or state agency, it is a straight cost item. For the optional policies, the contractor normally will not purchase full coverage because of the high costs involved. Instead, these policies will contain a deductible amount which represents an acceptable level of self-insurance (potential loss) to the contractor. These deductible amounts become an "uninsured losses" risk item in the contract. Insurance provides protection against losses associated with most unknown unknown risks of a catastrophic nature.

Risk Acceptance with Contingency. Contingency is a reserve account expressed in dollars and/or time to cover losses that do occur. Referring back to the discussion of the Monte Carlo method in Chapter 4, the contingency amount can be a product of the ranging process, the amount selected being that which keeps the probability of not overrunning the target within the desirable limits. The sum of planned profit plus contingency dollars in a contract represents the total ability of the contractor to absorb losses without experiencing a net loss on the project.

Risk Acceptance without Contingency. If competitive conditions preclude inclusion of a large contingency, then some risks must be accepted without contingency. If the actions discussed above have been taken, the remaining risks should show low potential loss value and/or contain a low probability of occurrence.

Risk Containment Actions

Recognizing that the losses assumed are not inevitable and could be either greater or smaller, management wants to contain risk. Effective risk containment may convert some or all of the contingency set-aside to additional profit. Below are brief discussions of some.

Contingency Planning. Thorough planning has always been a common characteristic of successful projects. By planning for both normal and contingency events, response to adverse situations can be speeded up and their effects minimized.

Qualified Personnel. Use of known, experienced personnel, extremely selective recruiting and use of formal training where required will best assure the presence of personnel qualified to deal with any situation.

Qualified Subcontractors. Use of prequalified subcontractors will help assure that work will meet quality and time requirements and not adversely affect other activities.

Safety/Loss Control Program. A strong loss control program will minimize human and material losses on a project plus contribute to lower Workers' Compensation costs on future projects.

Responsibility Allocation. Responsibility for control of risk should be assigned to the individuals or organizations with the greatest capability to control that risk along with a requirement for regular status reporting.

Strong Project Controls. A project controls operation that can provide timely and accurate reporting and analysis services for the staff enables identification of actual and potential problem areas in time for positive corrective action.

Constructability Analysis. In reviewing work for constructability, reduction of accident exposure should be made a key element in selecting work methods.

Pareto's Law Control. The attention of management should be focused on key risk items with lesser surveillance of the remainder.

Critical Items Reporting. A system should be established for special reporting of any situation that has affected or has the potential for significantly affecting cost or schedule so that these items can receive special attention.

Contingency Account Management. Contingency should be allocated to the various risk accounts and controlled account by account. These accounts are not necessarily the same control accounts used for cost and schedule control purposes. A typical risk control account may be "bulk materials quantity growth" or "cost growth, Phase I."

Substance Abuse Program. A well-planned and administered substance abuse program can help assure that all personnel are fit for duty, eliminate the distractions and delays associated with substance abuse problems on the job site and reduce the potential for accidents.

Training Programs. Special training programs designed for the project can develop needed personnel skills quickly, contribute to team building and otherwise contribute to the efficiency and successful interaction of project team members.

Rehearsals. For critical operations, rehearsals will reduce the potential for errors during the real operation.

Project Labor Agreement. On union projects, such agreements can eliminate unfavorable work practices and contribute to efficiency of labor and the maintenance of a favorable labor-management atmosphere.

Risk Re-evaluation. Throughout the life of the project, risk exposures should be re-evaluated so that timely control action can be taken and management attention can be refocused as necessary.

Crisis Management

Emergency planning has been identified as a control action of risk management. When speaking of emergency plans, one usually thinks of such examples as Fire Protection Plan, Hazardous Spill Plan or Extreme Weather Protection Plan. One additional plan that requires special mention is the Crisis Management Plan.

The Crisis Management Plan is intended to provide guidance to project personnel in the handling of situations which attract media attention and scrutiny. Typical examples are labor violence, a serious accident or collapse of a structure under construction. Such incidents will bring hordes of media to a site, all wanting photo or video coverage of the scene plus interviews with witnesses or anyone else willing to talk. In the confusion of a disaster, there is great potential for project personnel to compromise themselves and their companies or to alienate the general public through extemporaneous handling of the situation. Overall, a Crisis Management Plan should be available and well-known to key project personnel and include these features:

A copy of the Crisis Management Plan of the owner, if such a plan exists for the site, and the responsibilities for participating in that plan

Company policies concerning each type of crisis

A catalog of potential crises for which the project is most susceptible and, for each, special considerations in developing a response

A directory of company personnel to be notified

A directory of emergency or public agencies to be notified (for each category of crisis)

Identification of the Crisis Manager

Identification of official spokesperson(s)

Guidelines for handling of the media

Instructions to be given project personnel concerning release of information

Security measures to be taken to protect disaster areas and project property

Authorized recovery actions

Post-disaster handling of employees

6

CONTINGENCY MANAGEMENT

Overview

As described in Chapter 5, contingency accounts are appropriate for both cost and time for a project. If these accounts are to serve their intended purposes, they must be carefully managed.

In their approach to contingency management, project planners and managers must treat cost contingency as a line item of cost in an estimate which is intended to cover cost increases which have a reasonable probability of occurring. In that sense, it should be expected that some or all of the contingency account will be expended. But, as with all other cost accounts in an estimate, any savings will contribute to profit. Similarly, time set aside as contingency is a schedule activity which is expected to be consumed. As with any other schedule activity, any time savings will add to management's scheduling flexibility for later activities.

Contingency Cost Management

Although the contingency will have been established after consideration of all significant risk elements in the contract, the amount arrived at is initially a single bulk figure. The choice becomes one of managing it as a single line item account or somehow distributing it to parallel other accounts.

Managing contingency as a single account has these disadvantages:

There will be a natural tendency to draw down the account on a first-come, first-served basis. This carries with it the potential for exhaustion of contingency funds well before the project is over. Also, as this is happening, managers may feel a project is in better position cost-wise than it really is because early losses are being covered. This may delay initiation of needed corrective action.

There will be a problem of control. Every control account in a project, risk or otherwise, should be the responsibility of one individual to manage. The only person that can manage a project-wide account is the project manager. Such assignment will add to the heavy responsibilities already associated with that function and may cause contingency account management to be neglected. If contingency account control is left open, there will be no control.

Distribution of the contigency funds across the contingent accounts is the recommended approach. Thedistribution should reflect the breakdown of risks that were used in initially establishing contingency. Obviously, the amount will not be large enough to provide coverage for the maximum foreseeable losses in every account, but it can be distributed on such a basis. (If the Monte Carlo method is used, total contingency may be allocated to each critical cost element in proportion to the bottom line effect of its maximum potential overrun weighted by the probability of its overrunning, offset by the bottom line effect of its maximum potential underrun weighted by the probability of its underrunning. See Appendix for example of this method of contingency allocation.) Then, if losses do occur in accounts, contingency can be applied to the extent available. On projects where the work covered and associated contingency accounts are large, the responsible account manager may choose to further distribute the contingency funds using a form of drawdown curve that relates contingency reserves to amount of activity completed. Figure 3 is an example of such a drawdown curve. In developing this curve the planners have five contingency accounts to which a project contingency amount of 10 percent has been distributed. This distribution plus other data and calculations used to derive the curve are shown in Table 1.

Table 1
Data Relating to Contingency Drawdown Curve

(a)	(b) % Total cost	(c) % Contingency allocated	(d) Weighted contingency (b)x(c)	(e) Project stage when account complete
Account A	12	10	1.2%	80%
Account B	29	10	2.9%	50%
Account C	31	10	3.1%	80 %
Account D	6	10	0.6%	100%
Account E	22	10	2.2%	100%
	100		10.0%	

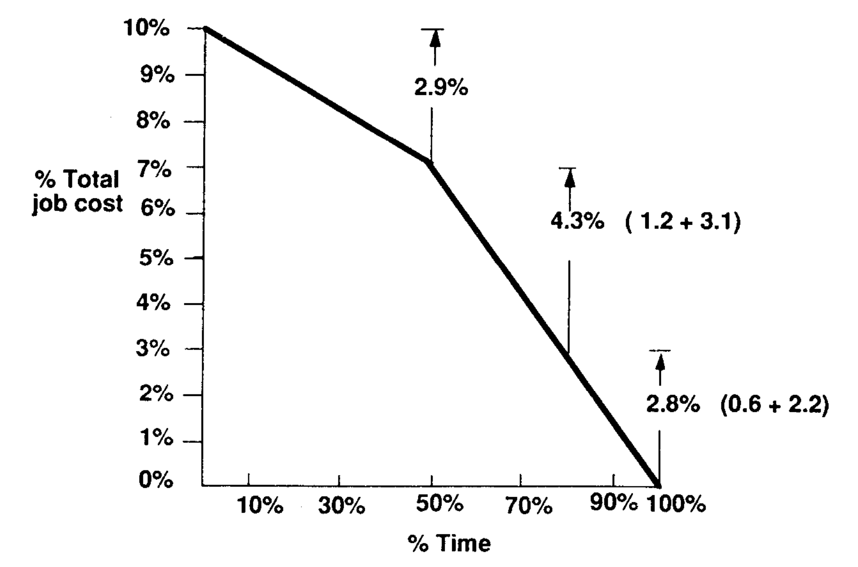

Figure 3. Contingency Drawdown Curve

Contingency should not be used to cover losses in accounts outside the group for which contingency was established; cost performance in these should be reported in terms of positive or negative variance. When losses in a contingent account exceed available contingency for that account, a negative variance will be reported for this account. If contingency funds still remain after the cost accounts they protect are completed, the excess is transferred to a general contingency account. Under this procedure, the managers will have a more realistic picture of cost performance and will be able to provide more timely response to problems. Control of each contingency subaccount should be assigned to the supervisor responsible for the activities for which the account was established, and its status should be reported along with the work items within that supervisor's area of control.

During the course of a project the risks should be regularly reviewed and contingency accounts adjusted, if necessary, to cover remaining risks.

Management of Schedule Contingency

The management of contingency time is subject to the same considerations as those applicable to cost. The contingency time could be treated as a single block of time at the end of the project, but it is best distributed over the project so that contingency time precedes each key milestone in the project. As with cost, this approach allows a more realistic and timely picture of schedule performance over the life of the project. Use of contingency time is best discussed and distributed during weekly or monthly look-ahead planning meetings of the project team. In effect, this places its control in the hands of the project manager, but that is realistic since many activities under a number of supervisors feed into each milestone date.

7

SUMMARY

Risk and uncertainty are inherent in all construction activities. They carry with them the potential for time, resource and monetary loss. These risks are divided among the project participants in various ways depending upon contract format and language. The fixed-price construction contract places particularly heavy risk upon the contractor, while a reimbursable contract places it on the owner.

Identification and measurement of risks must be an included element of pre-bid planning by the contractor. Failure to do so is equivalent to overlooking direct work items included in the contract. Because there are so many risks whose consequences can occur in a nearly infinite number of combinations, it is essential that the contractor use a structured approach for their evaluation. A probabilistic approach is a practical one and sophisticated commercial computer software programs are available to facilitate this analysis.

Accepting risk and providing contingency to cover it is only one form of risk control. Others include risk avoidance, risk sharing, risk reduction, risk transfer, insurance and risk containment.

While every risk carries with it the potential for a loss, this loss is not assured and there may be a potential for gain. Thus, risk containment efforts must be directed toward both preventing losses and taking advantage of any gain potential.

Contingency accounts are applicable for both cost and schedule. It is recommended that these accounts be distributed over the life of the project, that the responsibility for their control be clearly established and that their management be highly structured.

The Appendix presents an Example Risk Management Program that applies the methodology discussed in previous chapters.

APPENDIX

EXAMPLE RISK MANAGEMENT PROGRAM

Introduction

The risk challenge and a general methodology outlined for managing risk has been previously described. In this appendix, a model risk management program for a contractor bidding on a fixed-price engineering-procurement-construction project will be developed using the methodology described.

The Project

The project is a cogeneration facility to be constructed in a relatively narrow Colorado mountain valley in which a luxury ski area has been developed. Development consists of numerous hotels, condominiums, private homes, a shopping plaza, golf course and ski lifts serving multiple slopes. The new cogeneration plant is to support requirements associated with resort expansion that is to take place during the next several years. The facility is to be named "Sunset Power Station."

The time is August 1 and requests for fixed-price proposals for the project have been issued by the utility to selected contractors. As one of those contractors, we are evaluating the risk aspects of this project for purposes of determining whether we should bid on the project and, if we choose to bid, what our risk management plan will be.

The following additional details apply to the project:

- The general flow diagrams and operating criteria to be satisfied are as described in Figure 1.
- The altitude at the proposed facility is approximately 7,500'.
- As sketched in Figure 2, a single two-lane paved road connects the complex with a small town at the base of the valley and a major east-west turnpike. This road divides after two miles into two branches within the complex to serve the various facilities. The new power plant will be located ap proximately one-half mile from the main hotel-shopping complex and further up the valley.
- A major railroad passes through the town at the base of the valley.
- The estimated cost of $25 million is based on a similar unit built recently in another Colorado mountain location.
- At this time the economy of Colorado is sluggish, still suffering somewhat from the collapse of oil prices and the suspension of the shale oil projects. Construction work is almost totally open shop in this part of Colorado.

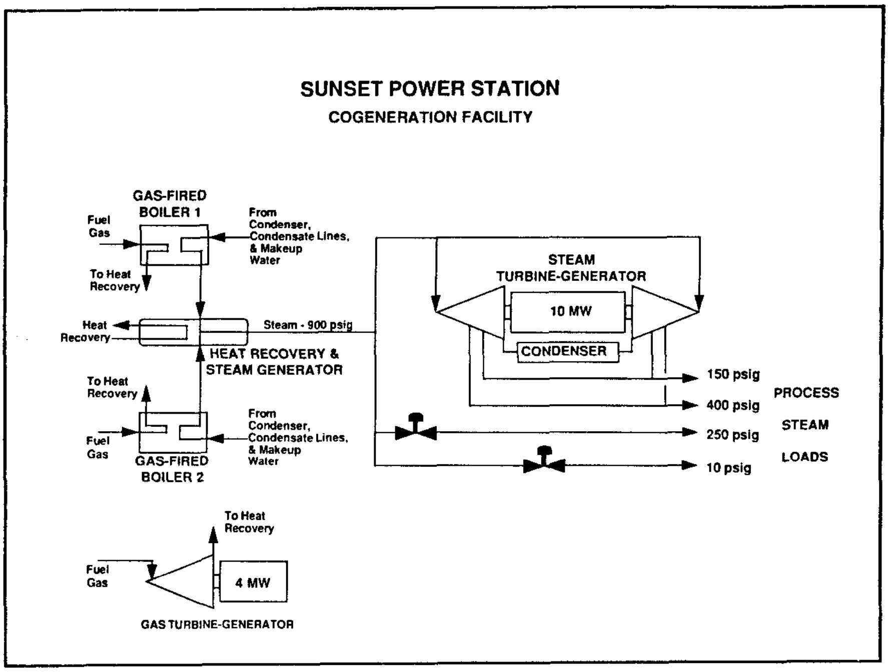

Figure 1. Flow Diagram and Operating Criteria

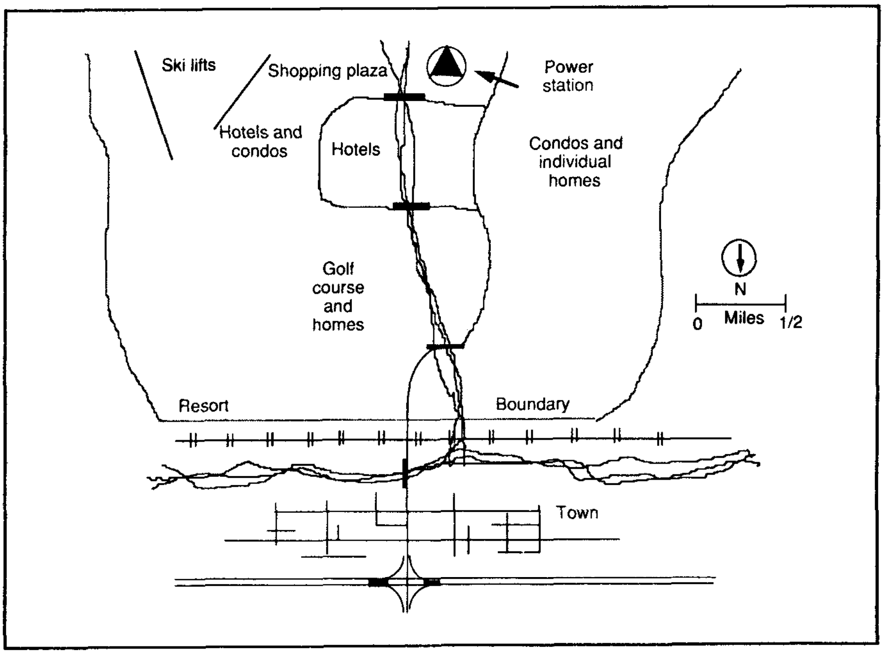

Figure 2. Location Map, Sunset Power Station

- The utility company has a contract for supply of natural gas upon completion of the project. Construction of the supply line is not part of this contract.
- The electrical distribution system outside the boundaries of the power plant is not part of this contract.
- It is expected that all permits will be available by December 1, the award date. However, the design-construction contract will not be awarded before all permits are approved. Thus, the utility requires that all bids be valid until March 1 with no adjustment of completion date.
- The selected contractor can choose to perform all engineering, procurement and construction functions using in-house resources, or may choose to subcontract any portion thereof. However, there will be a single contract for all functions between the utility and the contractor.
- Performance of the complete facility must be guaranteed.
- Required completion date is November 1, two years hence. Since the facility is needed to support new resort operations beginning with the winter season following completion, there will be liquidated damages of $10,000 per day for all unrecognized delays after that date.
- The contract will include a limited hold-harmless clause to protect the utility from any acts performed by the contractor or his subcontractors and vendors.
- Neither construction traffic nor construction activity is permitted within the boundaries of the resort before 7AM or after 7PM of any day. Further, no construction traffic or construction activity is permitted on Sundays.

Risk Management Program Approach

Reflecting the discussion of earlier chapters, the risk management program will be developed in these steps:

Identification of risks

Determination of options for handling risks

Measurement of risks to be covered by contingency

Determination of contingency

Development of plan for management of contingency

Summarizing overall risk management program

Since the objective of this example is simply to illustrate the methodology, we will not exhaust every detail in these steps.

Risk Identification

This is a fixed-price, design-build project. Generally, design-build projects are either totally cost reimbursable or handled in a two-step fashion with the design being reimbursable and the construction cost fixed through negotiation after design definition is at a certain point. However, the facility involved is of a type for which there is considerable industry experience so a fixed-price approach can be considered. Even so, this feature of the contract is certainly a major risk item. However, for purposes of management we will break it into its components.

Recalling that risks can be classified as knowns, known-unknowns and unknown-unknowns, we first concern ourselves with the apparent known risks. From the information available and our general knowledge of construction, these known risks should be on our list:

Contract clauses
- Hold-harmless clause
- Liquidated damages
- Performance guarantees

Time factors
- Available bidding time
- Available work days

Engineering factors
- Costs
- Quality of design
- Timeliness of design

Engineered equipment factors
- Cost
- Availability
- Inflation/escalation
- Ability to store and protect

Bulk and other materials
- Cost
- Availability
- Inflation/escalation
- Ability to store and protect

Area factors
- Altitude
- Remoteness
- Congestion
- Tourist/local population interferences
- Geology/subsurface conditions
- Short construction season; severe winters
- Transportation limitations; access/egress

Labor factors
- Uncertain availability; remoteness from population centers
- Uncertain quality
- Wage scales required to attract
- Possible substance abuse problems

Permanent materials factors
- Costs; inflation/escalation
- Lead times for key items
- Ability to protect during winter

Ability to perform
- Availability of construction drawings when needed
- Qualified supervisory personnel
- Needed support facilities
- Conflict with other construction in area

Environmental
- Damage to natural features
- Damage to existing facilities (roads, bridges, etc.)

Miscellaneous risks
- Delay in permit approval
- Insurable personnel and property losses
- Uninsurable personnel and property losses

Having compiled the list of significant known risks, the next step is to list the known-unknowns. The following items are of the type that should be on that list:

Abnormal weather conditions
- Early winter or late spring
- Flooding resulting from abnormally rapid snow melt
- Unusually heavy summer rain

Financial failure of key vendors or subcontractors

Violations resulting in OSHA or EPA stoppages or penalties

Strikes, embargoes, or other unexpected events elsewhere that affect equipment or materials availability

We cannot compile a list of unknown-unknown risks since these cannot be foreseen. However, we must still consider their potential for affecting the project and some protection will be included in the insurance portion of our risk management program.

Cataloging Risks and Control Options

The development of the lists above has forced us to expose the included risks of this contract. The next step is to organize these for purposes of control since many of the risks are interrelated. For example, labor costs are a function of wage scales, crew compositions, productivity and extent of rework. Productivity will be a function of many factors including quality of the workers, management competence, congestion, altitude, quality and availability of design drawings, availability of materials and availability of tools and construction equipment. It would be impractical to evaluate each of these elements independently so we will combine their effects into major risk categories.

While the total risk list can be organized in a number of ways, we have chosen to consolidate them into the categories below. Also, for each selected category, we will list options available to us for control of that risk. Later, we will select from these options for our final program.

All risks
- Avoid by electing not to bid on this project

Engineering cost overruns
- Transfer risk by subcontracting engineering
- Accept risk without contingency
- Accept risk but include as contingency item
- Employ strong scope and change control program

Craft labor cost overruns
- Transfer risk by subcontracting some or all construction work
- Accept risk without contingency
- Accept risk but include as contingency item
- Employ strong quality management program to control rework
- Use worker incentives to recognize superior quality and productivity

Engineered equipment cost overruns
- Accept risk without contingency
- Accept risk but include as contingency item
- Use competitive bidding to minimize cost

Other materials cost overruns
- Accept risk without contingency
- Accept risk but include as contingency item
- Utilize competitive bidding on supply contracts
- Utilize early buyout of selected materials to avoid later price increases

Schedule overruns and liquidated damages
- Transfer liquidated damages risk to vendors or subcontractors
- Accept risk without contingency
- Accept risk but include as contingency item in both schedule and budget
- Implement strong planning and control program to assure full integration of engineering, procurement and construction activity
- Integrate materials tracing with cost/schedule control
- Use strong expediting program for critical purchases
- Have contingency plans for critical operations
- Include incentive features in procurement contracts for early delivery and zero defects

Personnel, equipment or constructed facility loss

- Purchase insurance required by law or owner
- For other insurable losses, accept risk and self-insure without contingency
- For other insurable losses, accept risk and self-insure with contingency
- Purchase available insurance for other insurable losses and accept risk of uninsurable losses without contingency
- Purchase available insurance for other insurable losses and accept risk of uninsurable losses with contingency
- Utilize strong safety (loss control) program
- Develop emergency plans (accident, severe weather, etc.)

Performance guarantees

- Utilize comprehensive qualification program for vendors of all mechanical equipment
- Emphasize use of off-the-shelf, use-tested components instead of newly engineered items
- Transfer performance guarantees to vendors by contract

Special losses (OSHA fines, etc.)

- Accept risk without contingency
- Accept risk but include as contingency item
- Utilize strong safety (loss control) program
- Develop environmental protection and other emergency plans

Other risks inherent in project

- Pareto's Law management (critical items management)
- Comprehensive quality management program
- Establish staging area outside resort complex to permit work during excluded hours
- Maintain zero tolerance substance abuse policy
- Establish close screening policy for all hires
- Provide training as necessary for selected supervisory and craft personnel

As is apparent from the above listing there are many actions in addition to buying insurance and establishing a contingency that can become elements of a risk management program.

To continue with the example, it will be assumed that we have decided to bid on this project and to perform all engineering, procurement and construction using in-house resources or through direct hire. Also, we will assume that the decision has been made to: (1) buy insurance for insurable risks at levels normally used by the company, and (2) establish contingencies for both cost and schedule for those risks for which contingency is a control option. Determination of the amount of cost contingency is the next major task. Later we will choose additional control options to round out our program.

Contingency Determination

For those items for which setting aside a contingency amount is an option, we must follow a structured procedure to determine the collective amount. Two methods will be suggested. The first utilizes percentage markups (traditional method); the second is Monte Carlo, a special form of simulation. Both were briefly described in Chapter 4.

For the percentage markup approach, we isolate each of the risk elements for which a contingency is to be a part of its risk control. Then, for each of these elements, we establish the target cost (conventional target estimate) and a percentage markup or a lump sum for contingency. This markup is established through brainstorming by the project team. For our example, the following risk elements were selected for contingency. The target estimates and markups for each are assumed to be as listed in Table 1.

Table 1
Contingency Markup

		(Cost in $000)	
	Target	Markup	Contingency
Engineering	800	15%	120
Craft labor	6,500	20%	1,300
Engineered equipment	6,000	10%	600
Bulk materials	6,200	10%	600
Other project costs (overhead, etc.)	1,000	5%	50
Liquidated damages	0	LS	100
TOTAL PROJECT LEVEL COST	20,500		2,800

Under this procedure our assumptions have yielded a contingency account of $2.8 million dollars.

The second procedure is Monte Carlo as described in Chapter 4. To apply this method we first analyze the risk and opportunity of each critical element selected for contingency coverage. This is best done by personnel most familiar with the item in question who collectively establish a low, target and high cost value-i.e., the range. For purposes of definition, the low value can be treated as a value below which there is less than 1 percent chance of occurrence. Similarly, the high value will have less than 1 percent chance of being exceeded. The target value is that which would be selected under conventional single-number estimating. The results of this brainstorming session for this example are assumed to produce the ranges in Table 2. To keep this example as simple as possible the total cost is summarized in the six categories listed. In practice, more could be used. For example, labor cost could be broken down into crafts and these individually ranged (if each is a critical cost element).

Table 2
Cost Ranges

	(Cost in $000)		
	Low	Target	High
Engineering	600	800	1,200
Craft labor	4,800	6,500	11,000
Engineered equipment	5,500	6,000	7,500
Bulk Materials	5,300	6,200	8,100
Other project costs (overhead, etc.)	900	1,000	1,100
Liquidated damages	0	0	300
TOTAL PROJECT LEVEL COST	17,100	20,500	29,200

With the Monte Carlo program, only those cost elements which are critical are ranged. As explained in Chapter 4, in a conceptual or approximate estimate such as this, a cost element is critical if its maximum potential overrun or its maximum potential underrun would change the total cost of the project by more than 0.5 percent of the targeted bottom line estimate (0.2 percent in the case of a detailed or definitive estimate).

Since the targeted bottom line estimate of this project is $20,500,000, a cost element is critical (and should be ranged) if it can cause a total cost overrun of more than $102,500 (0.5 percent of $20,500,000) or a total cost underrun of more than $102,500. The data in Table 2 indicate that five of the six cost elements are critical. "Other project costs (overhead, etc.)" is noncritical since the maximum potential change which it can effect on the total cost of the project is $100,000. For that reason, it will be renamed "Noncriticals" and frozen at $1,000,000.

If they wish to do so, the estimators and management may further refine each range to include the probability that the target estimate will not be exceeded. For this example, assume that the results are those shown in Table 3.

Table 3
Cost Ranges and Probabilities.

	(Cost in $000)			
	Low	Target	High	Prob.*
Engineering	600	800	1,200	50%
Craft labor	4,800	6,500	11,000	40%
Engineered equipment	5,500	6,000	7,500	50%
Bulk materials	5,300	6,200	8,100	30%
Liquidated damages	0	0	300	
Noncriticals		1,000		
TOTAL PROJECT LEVEL COST		20,500	(*of not overruning target)	

Next, the Monte Carlo program is applied. This program costs the project 1,000 times on a computer to develop the overrun profile. For this example, the results are displayed in Figure 3.

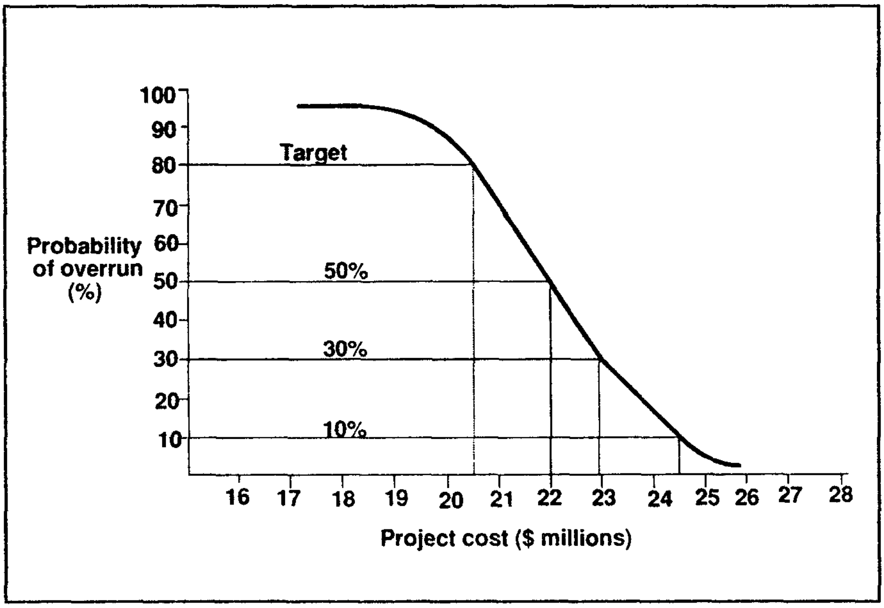

Figure 3. Overrun Profile

Note that the possible project costs are within the low and high extremes indicated in Table 2. Also, note that the target cost has an 80 percent probability of being overrun. This is a consequence of the fact that we foresee more potential for overrun both in amount and probability in the critical elements than we do for underrun. The 50 percent point is about $22 million.

Close review of this process and the resultant overrun profile reveals how we are combining both cost and contingency determination. We can also add our profit into the picture. Assume we decide to operate at the 70 percent level of confidence of not having a cost overrrun (i.e., a 30 percent chance of having an overrun). In this example, that project cost is about $23 million. If we wish to add our profit-say $1.5 million-our price to the owner would be $24.5 million. We can then be 90 percent confident of not losing money since Figure 3 indicates there is only a 10 percent chance of overrunning $24.5 million.

The Final Risk Management Plan

Having selected contingency, we complete our risk management plan by additionally selecting other risk control options from those available. Figure 4 is a spreadsheet representing the complete program for this project

Risk Elements \ Control Actions	Purchase insurance	Accept w/ contingency	Accept w/o conting.	Sub/Vendor prequal.	Transfer - subcontract	Transfer - vendor	Plan & controls prog.	Qual. mgmt. program	Mat'l mgmt. program	Safety/loss control	Emergency plans	Contingency plans	Selective hiring	Substance abuse policy	Supv. training	Off-site staging	Critical items mgmt.	Change control	Competitive bidding	Early buyout
Engineering overrun		■					■						■				■	■		
Craft labor overrun		■		■	■		■	■					■	■	■		■	■	■	
Engineered equip. O/R		■		■					■								■	■	■	
Bulk materials O/R		■		■				■	■						■		■	■	■	■
Schedule O/R (Liq. Dam.)		■			■	■	■	■	■	■		■				■	■	■		
Insurable losses	■									■	■			■	■					
Uninsurable losses			■							■	■			■	■					
Performance guar.			■	■		■														
Special losses			■							■	■				■					
Miscellaneous			■										■		■		■			

Figure 4. Sunset Power Station Risk Management Program Matrix

The Schedule Risk Management Plan

To this point all attention has been focused on items affecting cost. Schedule performance certainly affects cost and certain of the scheduled control actions in our Risk Management Plan simultaneously control both cost and schedule. Thus, it is recommended that contingency time be included in time planning. The owner's need date is fixed so all contingency time must be incorporated prior to that time. Total contingency time can be determined using either a traditional or simulation approach as discussed in Chapter 4. This time should then be distributed among phases of the project based on a weighting system which considers the relative time risks among phases. If remaining time available for performing the work is less than that considered normal, it is suggested that schedule compression techniques as outlined in CII Publication 6-7, *Concepts and Methods of Schedule Compression,* be used to shorten planned time to fit available time. On the schedule, treat the contingency time in each phase as a schedule activity at the end of the phase.

Managing Contingency

It was recommended in Chapter 6 that the contingency set aside for the project be managed in a fashion that reflects the way it was determined. In this example, five accounts were critical and ranged. Thus, the contingency should be allocated to those five for purposes of control. For a ranged account, the allocation should be based on the bottom line effect of its maximum potential overrun weighted by the probability of it overruning, offset by the bottom line effect of its maximum potential underrun weighted by the probability of it underruning.

In this example, assume we wish to operate at a confidence level of 70 percent. This means we will set aside a contingency of $2.5 million ($23.0 - $20.5). The allocation of this $2.5 million is shown in Table 4.

Table 4
Contingency Allocation

(a)	(b) Max O'run	(c) Prob. O'run	(d) (b)x(c)	(e) Max U'run	(f) Prob. U'run	(g) (c)x(f)	(h) (d)-(g)	(i) (h)/39.6	(j) Allocate (i)x2500
Engineering	400	50%	200	200	50%	100	100	2.5%	62.5
Craft labor	4.500	60%	2,700	1.700	40%	680	2,020	50.8%	1270.0
Engineered equip.	1,500	50%	750	500	50%	250	500	12.6%	315.0
Bulk materials	1,900	70%	1,330	900	30%	270	1,060	26.6%	665.0
Liquidated damage	300	100%	300	0	0%	0	300	7.5%	187.5
Noncriticals	0	0%	0	0	0%	0	0	0.0%	0.0
Total Project Level							3,980	100.0%	2.500.0

During project execution, a Contingency Drawdown Curve as described in Chapter 6 can be used for status reporting. Also, Chapter 6 of CII Publication 6-5, *Project Control for Construction,* describes a Contingency Account variance register that can be used for individual account control.

A Word About Risks and Opportunities

Referring to Table 4, columns "(d)" and "(g)" are, respectively, excellent measures of the major risks and opportunities in this sample project. The values in these columns are used to construct a *Risk/Opportunity Profile* as shown in Figure 5. This particular report is an excellent example of how the Monte Carlo approach capitalizes on Pareto's Law and the management by exception principle to assist engineers and managers in decision-making.

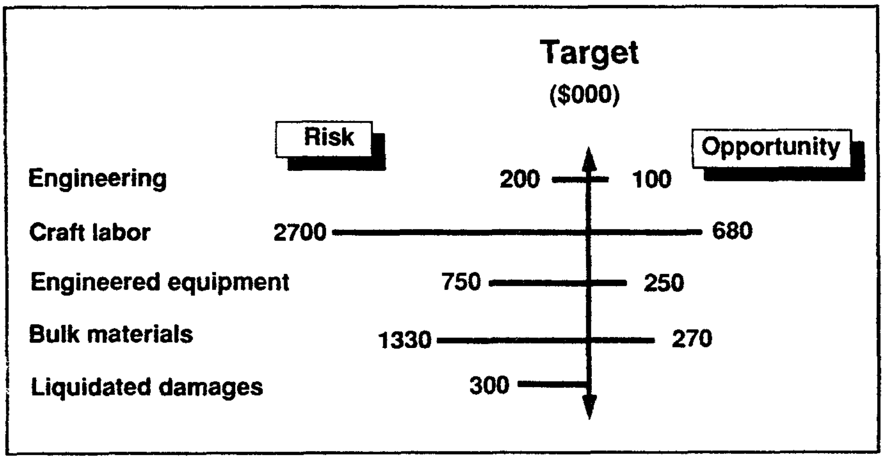

Figure 5. Risk/Opportunity Profile

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Cost/Schedule Controls Task Force Membership

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Jodie Caldwell, Gilbert/Commonwealth
Jerry Davis, Shell
Jim Diekmann, University of Colorado
Gary Gehrig, Colorado State
Dan Halpin, Purdue
Richard Mayes, Rust
Carl McKenry, Ford, Bacon & Davis
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*Principal Author

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