Systematic Risk Management Approach for Construction Projects

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Abstract: Risk is inherently present in all construction projects. Quite often, construction projects fail to achieve their time, quality, and budget goals. A risk model entitled construction risk management system (CRMS) is introduced to help contractors identify project risks and systematically to analyze and manage them. The CRMS model is a logical substitute for the traditional intuitive unsystematic approach currently used by most contractors. The influence diagramming technique and Monte Carlo simulation are used as tools to analyze and evaluate project risks. Alternative risk management strategies are suggested. Such strategies include: risk avoidance, risk transfer, risk retention, loss reduction, and risk prevention and insurance.

Introduction

Construction, like many other industries in a free-enterprise system, has sizable risk built into its profit structure. From beginning to end, the construction process is complex and characterized by many uncertainties.

Most contractors, however, have developed a series of rules of thumb that they apply when dealing with risk. These rules generally rely on the contractor's experience and judgment. Rarely do contractors quantify uncertainty and systematically assess the risks involved in a project. Furthermore, even if they assess these risks, they even less frequently evaluate the consequences (potential impact) associated with these risks. One reason might be the lack of a rational straightforward way to combine all the facets of risk systematically into a prioritized and manageable scheme.

The main objective of this paper is to introduce a new risk model entitled *Construction Risk Management System (CRMS)*. The proposed model provides a formal, logical, and systematic tool that helps contractors in identifying, analyzing, and managing risks in a construction project.

What Is Risk?

Risk is a pervasive part of all actions. It would seem on the surface that the term "risk" is a simple well-understood notion. However, its definition is elusive, and its measurement is controversial (Lifson and Shaifer 1982).

In the literature, the word "risk" is used in many different meanings with many different words such as hazard or uncertainty (Boodman 1977; Faber 1979; CERL 1978; Lifson and Shaifer 1982; Hertz and Thomas 1983). It is found that there is no uniform or consistent usage of the word risk in the literature. In addition, most definitions of risk have focused only on the downside associated with risks such as losses or damages, and neglected the

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up side or opportunity such as profit or gains. This work recognizes both sides of risk, i.e., the downside and its counter-opportunity.

Since the existing literature often uses the terms risk and uncertainty interchangeably we will clarify the use of these terms for the purpose of this paper. "Uncertainty" will be used to represent the probability that an event occurs; thus a "certain" event has no uncertainty. We will define risk as: "The exposure to the chance of occurrences of events adversely or favorably affecting project objectives as a consequence of uncertainty." With this definition, risk is characterized by the following components:

The risk event: What might happen to the detriment or in favor of the project.

The uncertainty of the event: How likely the event is to occur, i.e., the chance of the event occurring. A sure or certain event does not create risk, although it may create gain or loss.

Potential loss/gain: It is necessary that there be some amount of loss or gain involved in occurring of the event, i.e., a consequence of the event happening. We will use "loss" as a general term to include personal injury and physical damage, and "gain" to include profit and benefit.

Symbolically, we could write this as: Risk = f(Uncertainty of event, Potential loss/gain from event).

From this definition, uncertainty and potential loss or gain are necessary conditions for riskiness. It may seem strange to refer to uncertainties about potential gains as risks. However, even in situations of potential gains, uncertainty is unattractive since the knowledge of the exact gains is unknown, and contractors are reluctant to give credit to an unknown gain.

Relationship of Risk Management to Insurance Management

In construction, it is observed that the risk management function has been closely linked with insurance. Many contractors think of risk management as insurance management where the main objective is to find the optimal economic insurance coverage for the insurable risks. In fact, this viewpoint is shared by others such as the International Risk Management Institute, which published a manual entitled "The Construction Risk Management." The manual focuses on insurance management rather than risk management (International Risk Management Institute 1987).

It is emphasized in this work that risk management, as next defined, has a broader meaning and involves more than just insurance management. It is a quantitative systematic approach to managing risks faced by contractors. It deals with both insurable as well as uninsurable risks and the choice of the appropriate technique or techniques for treating those risks.

For the purpose of this paper, and in the context of project management, risk management is defined as: "A formal orderly process for systematically identifying, analyzing, and responding to risk events throughout the life of a project to obtain the optimum or acceptable degree of risk elimination or control."

Writers such as Fraser (1978) have endeavored to systematize the process of risk management and establish a generally acceptable terminology. Healy (1981), after reviewing various authors, has developed one approach which is suitable for risk management in giant projects. Wideman (1986) has proposed a theoretical framework of a construction risk management model. With respect to this paper, we will improve and modify the conceptual model proposed by Wideman, and convert it into a completely defined management model of risks in construction projects. The proposed model captures the conceptual ideas of the Wideman's model and places them into a quantitative or functional framework (Al-Bahar 1988).

Construction Risk Management System—CRMS Model

The proposed new model is entitled *Construction Risk Management System (CRMS)* (Al-Bahar 1988). The model provides an effective systematic framework for quantitatively identifying, evaluating, and responding to risk in construction projects. With CRMS particular emphasis is placed on how to identify and manage risks before, rather than after, they materialize into losses or claims. The proposed CRMS consists of the following four processes:

- Risk identification.
- Risk analysis and evaluation.
- Response management.
- System administration.

Note that these four processes are arranged in a logical and sequential order and provide the contractor with a systematic way of managing risk.

The CRMS has the features of a systematic framework of risk management which is methodical, objective, analytical, has quantitative measurement, and is self-contained. First, the CRMS framework involves a definite method. It has an orderly and consistent way of treating complex project risks. Second, the method is objective rather than intuitive, and the results can be verified and documented. Third, risk managed systematically is subject to analysis and evaluation. This analytical effort, in turn, enables assessment of the potential impact of risk quantitatively. Finally, the system is complete in itself. It exists as an entity. The linkage between the different four processes provides a closed-loop feedback to update the information in the system and to capture the interaction between these processes. In the following sections, we will discuss each process briefly. For further detail, refer to Al-Bahar (1988).

Risk Identification Process

Risk identification is the first process of the CRMS model. It is of considerable importance since the processes of risk analysis and response management may only be performed on identified potential risks. Therefore, the process must involve an investigation into all possible potential sources of project risks and their potential consequences.

Hence, with respect to this paper, risk identification is defined as: "the process of systematically and continuously identifying, categorizing, and assessing the initial significance of risks associated with a construction proj-

J. Constr. Eng. Manage., 1990, 116(3): 533-546

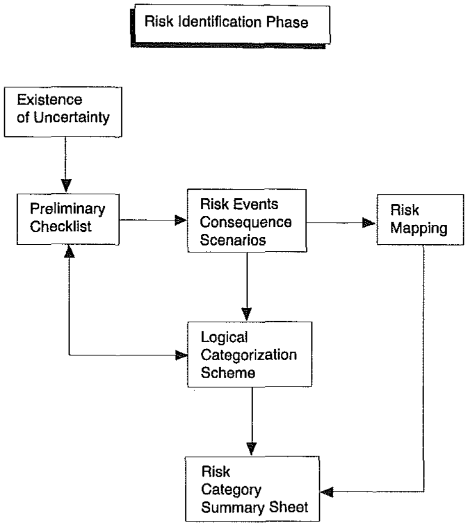

FIG. 1. Risk Identification Process Framework

ect." As shown in Fig. 1, there are six steps involved in the risk identification process. The following sections will discuss each step separately.

Preliminary Checklist

The preliminary checklist of potential project risks is the starting point for identifying risk. A failure to recognize the existence of one or more potential risks may result in a disaster or foregoing an opportunity for gain resulting from proper corrective action. Risks of all types that affect productivity, performance, quality, and economy of construction should be included.

Many contractors utilize commercial checklists or survey questionnaires, in addition to their own past experience, to assist in preparing their checklist of potential risks. These checklists can be used as a guide or starting point for the development of a more accurate and precise checklist for the specific project in hand. Despite the fact that substantial effort has been devoted to establishing a systematic identification process, success is still heavily dependent upon the experience combined with intuition of the contractor identifying the risk. A new identification system consisting of an extensive data base of construction problem statements has been developed at the University of Texas (Ashley and Perng 1987).

Identify Risk Events/Consequence Scenarios

The second step of the risk identification process is the definition of a set of credible risk events/consequence scenarios. This set represents all reasonable possibilities associated with the realization of each primary source of risk included in the preliminary checklist. The consequences can include economic gain/loss, personal injury, physical damage, time and cost savings/overrun. Since most risks that evolve in construction projects are financially related, the emphasis is on the financial consequence criterion as a uniform basis of assessment. Any other criteria can be valued in terms of financial gain or loss.

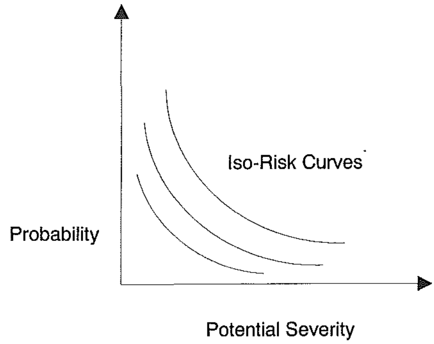

FIG. 2. Risk Mapping Concept

Risk Mapping

In event risk mapping, a graph of two dimensions or scales is proposed to construct the risk map. In the first dimension, uncertainty will be assessed with regard to the probability of occurrence. In the second dimension, risk will be assessed with regard to its potential severity. Such a two-dimensional graph is considered an important graphical representation, and will enable the project manager to assess the relative importance of an exposure to a potential risk in an early stage. As previously noted, *risk* is a function of the interaction of uncertainty and potential gain/loss, and the proposed mapping function presents *Iso-Risk* curves where each curve represents equivalent risk but differences in uncertainty and gain/loss. The further the curve is from the origin the greater the risk. Fig. 2 shows this risk mapping.

Risk Classification

The purpose of forming a taxonomy or classification of risks is twofold: First, to expand the contractor's awareness about the risk involved. Second, we need to classify risks because the strategies a contractor adopts to mitigate risks will vary according to their nature.

Several authors have attempted various means of classifying risk in construction projects. Some of these authors include Baldwin (1971), Mason (1973), Ashley (1977, 1981), Johnson and Rood (1977), and Erikson (1979). However, it is evident that all these classification schemes lack the means of classifying the risk properly. No attempt has been made to classify the risk by its nature or its potential impact. Furthermore, the preceding authors have attempted to list potential risks and have failed to recognize the relationships between different risk events. Hence, the categories or classification groups do not appear to result from a logical development.

For the purpose of this paper, a logical and formal classification scheme of risk is proposed. The proposed scheme classifies the potential risks according to their nature and potential consequence. Such classification enables a fuller appreciation of the factors influencing the risk, consequences, and different parties involved. The proposed classification scheme is composed of six risk categories. The selected categories illustrate the diversity of risks and provide a stimulus to examine the full breadth of exposure to risk so that contractors don't focus on one type and forget others. Table 1 shows

J. Constr. Eng. Manage., 1990, 116(3): 533-546

TABLE 1. Proposed Classification Scheme

Risk category (1)	Typical risks (2)
Acts of God	Flood, earthquake, landslide, fire, wind, lightning
Physical	Damage to structure, damage to equipment, labor injuries, material and equipment fire or theft
Financial and economic	Inflation, availability of funds from client, exchange rate fluctuation, financial default of subcontractor, nonconvertibility
Political and environmental	Changes in laws and regulations, war and civil disorder, requirements for permits and their approval, pollution and safety rules, expropriation, embargoes
Design	Incomplete design scope, defective design, errors and omissions, inadequate specifications, different site conditions
Construction-related	Weather delays, labor disputes and strikes, labor productivity, different site conditions, defective work, design changes, equipment failures

the categories and some of the typical risks in every risk category. While the list of potential risks in every category is neither complete nor exhaustive, it does represent the majority of typical project risks and demonstrates the advantage of a logically developed classification scheme.

Risk Category Summary Sheet

This is the final step in risk identification process. The summary sheet will integrate the participation of all personnel involved in the project management team. Such participation is considered very important in risk identification process, since judging the significance of any risk cannot be delegated to a single person. As information changes or different risk exposure develops, the summary sheet is updated. In this way, it becomes a living picture of management's understanding of the project risks. Fig. 3 shows an example of a summary sheet where the conditional risk variables provide insight into the interaction of one event with other listed events.

Name of Project: ....

Comments: ....

Date: ....

Prepared By: ....

Risk Events	Description of Risk Event	Conditional Risk Variables
1. .... 2.		

FIG. 3. Risk Category Summary Sheet

J. Constr. Eng. Manage., 1990, 116(3): 533-546

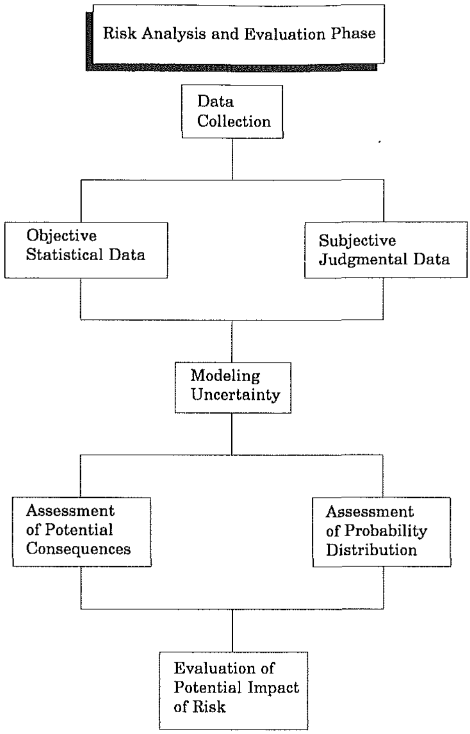

FIG. 4. Risk Analysis and Evaluation Process Framework

Risk Analysis and Evaluation Process

It is not enough to identify risk. From the risk-mapping concept, some of the risks identified are considered by project management to be more significant and selected for further analysis. What is needed now is to determine their significance quantitatively, through probabilistic analysis, before the response management stage.

The risk analysis and evaluation process is the vital link between systematic identification of risks and rational management of the significant ones. It forms the foundations for decision making between different management strategies. With respect to this paper, risk analysis and evaluation is defined as: "A process which incorporates uncertainty in a quantitative manner, using probability theory, to evaluate the potential impact of risk." Fig. 4 is a schematic presentation of the various components of the process. The following sections will discuss each component separately.

Data Collection

The first step in the risk analysis and evaluation process is the collection of data relevant to the risk exposure to be evaluated. These data may come from historical records that the contractor experienced in past projects. In this case, such data will be considered as objective or statistical in nature, and may be presented as histograms or frequency distributions.

Unfortunately, in many cases, directly applicable historical data concerning the risk are not available in adequate amount, and a subjective assessment will be required. Contractors are generally reluctant to document or record data as they come from the field during construction or as the project proceeds. Even if they do so, the data are incomplete. Hence, available data are mainly subjective in nature and must be obtained through careful questioning of experts or persons with the relevant knowledge. For further information on subjective data and methods of eliciting subjective probability, refer to Staël von Holstein (1970), Spetzler and Staël von Holstein (1984), Bunn (1984), Huber (1974), and Al-Bahar (1988).

Modeling Uncertainty

With respect to this paper, modeling of uncertainty of a risk exposure refers to the "explicit quantification of likelihood of occurrence and potential consequences based on all available information about the risk under consideration." Likelihood of occurrence will be presented in terms of probability, and potential consequences will be presented in financial monetary terms.

Probability is considered as an explicit way of dealing with uncertainty. It is a device that permits management to incorporate all the available information concerning the likelihood of occurrence of a risk event into a single or combined number. We will adopt the definition of probability as a subjective judgment of opinion or degree of belief that the risk event will occur. This allows the contractor to use his logic, intuition, and experience to assess probability values based upon any amount of data available to him.

Evaluation of Potential Impact of Risk

Having modeled the uncertainty of different risk events, the next step is to evaluate the overall impact of these risks in a single global picture. This evaluation will combine the uncertainty of an event with the potential consequences. Many analysts use "expected value" theory, where the product of the uncertainty and the expected gain/loss is taken as the financial magnitude of risk for a given event. The sum of financial risk for all events will provide the global evaluation of risk for the project. In most instances this will provide sufficient input for the decision-making phase.

Al-Bahar (1988) suggested two more sophisticated methods of analysis which included influence diagrams and Monte Carlo simulation. The first had the advantage of providing a graphical representation of the interaction between events and the latter provided ease in evaluation. Those interested may wish to refer to this work.

Response Management Process

Having identified the risk exposure, and evaluated probabilistically its potential financial impact, it is time to take action. The contractor will formulate suitable risk treatment strategies. These strategies are generally based on the nature and potential consequences of the risk. The objective of these strategies is twofold: (1) To remove as much as possible the potential impact; and (2) increase control of risk.

This dual notion of reducing the potential impact and increasing risk control is very important, as shown in Fig. 5. A combination of very high financial impact and low controllability would represent the upper right-hand corner, which we would call "unfavorable" extreme. The left hand corner represents the other extreme, which we would call "favorable," where the

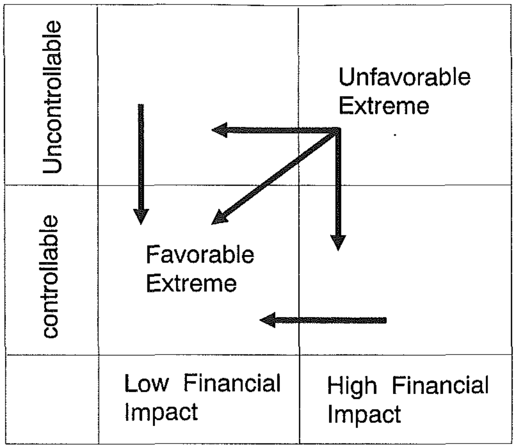

FIG. 5. Objective of Response Management Strategies

contractor has very high controllability and low financial impact. It is emphasized that any movement in any direction of the arrows shown is considered to be desirable.

In general, there are two basic approaches to managing a risk. The first is through measures aimed at avoiding or reducing the probability and/or potential severity of losses occurring. Such an approach is called risk control. The second is through making provisions to finance the losses that do occur. Such an approach is called risk finance. With this in mind, the response management process is composed of two steps. These steps are:

- Development of alternative risk management strategies.
- Recommendations and assignment of alternative strategies to project risks.

Development of Alternative Strategies

Within the framework of risk management, there are five alternative strategies:

- Risk avoidance.
- Loss reduction and risk prevention.
- Risk retention.
- Risk transfer (noninsurance or contractual).
- Insurance.

The purpose of the following discussion is to explain briefly the basic nature of these alternative responses or strategies, their attributes, and their basic characteristics.

Risk Avoidance. Avoidance is a useful, fairly common strategy to managing risks. By avoiding a risk exposure, the contractor knows that he will not experience the potential losses that the risk exposure may generate. On the other hand, however, the contractor loses the potential gains (opportunity) that may have been derived from assuming that exposure.

To illustrate, if a contractor is concerned about potential liability losses

J. Constr. Eng. Manage., 1990, 116(3): 533-546

associated with asbestos material or hazardous waste, he could avoid the risk by never acquiring any project that involves operations with such materials. Similarly, a contractor may avoid the political and financial risks associated with a project in a particular unstable country by not bidding on projects in this country.

Loss Reduction and Risk Prevention. The second risk management strategy is loss reduction and risk prevention programs. These programs are directed towards decreasing the contractor's exposure to potential risk by two ways: (1) Reducing the probability of a risk; and (2) reducing the financial severity of risk if it does occur. For example, the installation of antitheft device on construction equipment may reduce the chances of theft. A building sprinkler system, on the other hand, may reduce the financial severity caused by fire.

Loss prevention programs are considered important for two reasons. First, there is the effect on insurance premiums. It is found that by adopting a loss-prevention program, the insurance premiums are reduced significantly. Second, the success of a risk-retention program is a direct function of the contractor's ability to prevent potential risks and reduce their severity.

Risk Retention and Assumption. Risk retention is becoming an increasingly important aspect of risk management when dealing with project risks. Risk retention is the internal assumption, partially or completely, of the financial impact of risk by the firm. In adopting the risk-retention strategy, however, it is important to distinguish between two different types of retention. Risk retention can be either planned or unplanned.

A planned risk retention is a conscious and deliberate assumption of recognized or identified risks by the contractor. Under such a plan, risks can be retained in any number of ways, depending upon the philosophy, the particular needs, and the financial capabilities of the contractor. On the other hand, unplanned risk retention exists when a contractor does not recognize or identify the existence of a risk and unwittingly or unconsciously assumes the loss that could occur. For some firms, the task of risk identification has been so poorly performed that far too much risk is being passively retained. A related form of unplanned retention occurs when the contractor has properly recognized the risk exposure but has underestimated the magnitude of the potential losses.

Risk Transfer (Noninsurance or Contractual Transfer). In general, risk transfers are possible, through negotiations, whenever the contractor enters into a contractual arrangement with various parties such as an owner, subcontractors, or material and equipment suppliers. These noninsurance transfers differ from insurance in that the transferees (1) Are not insurers, and (2) due to inadequate historical data or their inability to adequately evaluate risk exposure, transferees usually do not accept enough exposure units for their losses.

Most noninsurance risk transfers are accomplished through provisions in contracts such as hold-harmless agreements and indemnity clauses or contractual adjustments. For example, adjustment in price where an extra compensation will be granted to the contractor if different subsurface conditions are encountered. The essential characteristic of the contractual transfer is that the potential consequences of the risk, if the risk does occur, are shared with or totally carried by a party other than the contractor.

Insurance. Commercial insurance is probably the most important and

J. Constr. Eng. Manage., 1990, 116(3): 533-546

frequently used method of handling risk that is employed by contractors. In fact, as mentioned earlier, many contractors think of risk management as insurance management. The majority of contractors rely upon insurance for the more serious loss exposures through the purchase of an insurance policy with certain deductibles.

Regardless of the form of deductibles, the obvious effect is a reduction in the premiums for a given amount of insurance protection. Loss-adjustment expenses are also reduced for the insurer. These two reasons explain why deductibles are usually used, especially when the frequency of small losses is fairly high. The difference between the response option of insurance and transfer is that insurance only shifts the financial potential consequences of the risk, whereas transfer also involves shifting responsibility for the risk.

Assignment of Alternative Strategies to Project Risks

The assignment of risk-management strategies to project risks differs from one contractor to another and from one project to another. During the assignment process a contractor considers the severity of potential risk, its probability of occurrence, and the resources that are available to counteract the potential loss if the risk occurs. With this approach, the probability of occurrence ranks equally with the severity of risk. It is not our purpose to have one set of recommendations for all project risks. The objective is to recommend alternative risk management strategies which give better control and reduce the financial impact of risk.

A tabular summary of the alternative risk management strategies described in this work is given in Fig. 6. A single one of these strategies is rarely used alone to handle a particular risk. It is much more common to use several of these strategies in combination for each type of risk.

System Administration

The final phase of the CRMS model is administering the risk-management process. Two important aspects of the system administration are considered: (1) Corporate risk management policy formulation; and (2) review and monitoring of the CRMS model functions.

Corporate Risk Management Policy

In many construction firms, we observed that the responsibility and attendant authority for carrying out a company's risk management policy is still ill-defined. This may result in gaps in coverage, underinsurance as well as overinsurance, excessive premiums, and overlapping of insurance coverage. The first step, then, is to set policies, procedures, goals, and responsibilities for risk management. Many contractors have begun to realize the need to establish a more formal risk management function in their organization.

A risk management policy is a formal plan, procedure, or document that outlines the rules within which the risk manager may operate. It provides guidelines for consistent actions in managing the risks. The main advantage of having such a definite policy is that once the guidelines are adopted, the risk manager does not have to restudy recurring problems before making decisions (Greene and Trieschmann 1984).

Records and Reports

Keeping appropriate records is essential for the risk-management function.

Type of Risk Category	Risk Category	Risk Management Strategies	Possible Counteractions
Fundamental & Speculative - Impersonal - Loss/Gain	Financial & Economic - Inflation - Foreign Currency Fluctuation - Exchange Rate Changes - Default by Sub-Contractors and Suppliers	Risk Retention Risk Transfer/Sharing Avoidance	- Escalation Clause - Price Contingency in the Bid - Project Financing by a Reputable Owner - Owner Purchase of Equipment & Material - Providing Performance Bond and Prequalification of Suppliers - Forward Contracts for Hedging Exchange Rate Changes
Particular & Speculative - Personal - Loss/Gain	Design - Inadequate Design - Errors and Omissions - Insufficient Detailing - Different Subsurface Conditions	Risk Transfer Avoidance	- Changed Condition Clause (Delay) - Contractor Participates in Design - Adoptable Design/Construction Methods - Change the Original Design
Fundamental & Pure - Impersonal - Loss/No Loss	Political & Environmental - Changes in Laws & Regulations - War and Civil Disorder - Expropriation - Embargoes - Pollution & Safety Rules	Insurance Risk Transfer Loss Prevention and Reduction	- O.P.E.C. and A.I.D. Insurance - Contingency Planning - Contractual Clauses for Schedule Delays and Additional Payments - Clear Contract Clauses - Protection and Safety Programs
Particular & Speculative - Personal - Loss/Gain	Construction Related - Weather Delays - Labor Disputes and Strikes - Different Site Conditions - Defective Work - Equipment Failure & Theft - Labor Injuries & Accidents	Risk Retention Loss Reduction and Prevention Insurance	- Physical Contingency in the Bid - Insurance for Liability from Accidents - Contract Clause for Time Extension Due to Delays - Safety and Training Programs for Employees - Planning Procurement Activities in Advance - QC/QA Programs
Particular & Pure - Personal - Loss/No Loss	Physical - Damage to Permanent Structures - Damage to Material and Equipment in Transit - Personal Injuries - Fire Damage	Risk Transfer Loss Reduction and Prevention Insurance	- Builder's Risk Insurance - Adequate Site Supervision - Contractual Clause for Delays - Safety and Accident Prevention Programs -Contingency Plan
Fundamental & Pure -Impersonal - Loss/No Loss	Acts of God - Flood - Earthquake - Fire - Collapse and Landslide	Insurance Risk transfer	- Insurance Carried by Owner - Contractual Clauses for delay and Payments for Incurred Damages - Contingency Plan

FIG. 6. Summary of Risk Management Strategies and Possible Counteractions

This is because these records form the basis for reports emanating from the risk-management function. They provide the statistical data needed in the process of deciding on an appropriate course of action in regard to risk treatment. The contractor should maintain records from the job site that might be unique to the risks envisioned in the project. Such records include risk frequency, risk severity and consequences, and other related information.

Evaluation of Risk-Management Process and Review

Evaluation of the CRMS model results is an effort to improve the procedures of risk identification, analysis and evaluation, and response management. It must be recognized that the business environment and the contractors operating within it are subject to constant changes. Therefore, an effective risk management program is not static but must be dynamic and ongoing. The various strategies or techniques adopted to handle project risks must be monitored and adjusted to compensate for changes in risk levels associated with changes in the firm's operations, the business environment, and the insurance industry. The Risk Identification concepts described in this paper were utilized to define risks for the World Bank-financed Jamuna Multipurpose Bridge project in Bangladesh; details are presented in Al-Bahar (1988). Risk evaluation on this project was performed by Monte-Carlo Simulation rather than the "expected value" notation presented earlier.

Conclusions

The risk management concept is relatively new to the construction industry. In this paper, it is significant that risk management has been extended well beyond the normal confines of Insurance. This is a realization that is no longer questioned by the industry. The logical extension offered in this paper is the systematic analytical approach starting with risk identification and its mapping, probabilistic risk analysis and evaluation of significant risks, and the development of alternative risk management strategies. Concepts described in this paper define a multiple step process for risk management; it is expected that contractors may wish to implement these concepts in varying degrees. Small firms may utilize the classification concepts to provide a better view of total risk and use these results to determine if the project is worth bidding. Larger firms may desire to blend the concepts into their existing insurance programs, maintaining a dynamic risk evaluation program for the life of the project as suggested. Additional work in the area of risk management is currently underway at the University of Colorado, Boulder (Professor J. Diekmann), and the University of California at Berkeley (Professor D. Ashley). This research will be continued for an improved understanding of the risk facing contractors on a daily basis.

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