APPROACHES FOR MAKING RISK-BASED GO/NO-GO DECISION FOR INTERNATIONAL PROJECTS

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ABSTRACT: The world economy is becoming more global due to agreements such as the ''Uruguay Round'' in the General Agreement on Tariffs and Trade. The globalization of the construction industry provides tremendous opportunities for contractors to expand into new foreign markets. However, international construction involves all of the uncertainties common to domestic construction projects as well as risks specific to international transactions. Consequently, in opposition to the worldwide globalization trend, only 19% of the U.S. top 400 contractors actively seek international contracts. This paper discusses current approaches related to entry decisions into international construction markets. It then develops a comprehensive approach for making stable and systematic go/no-go decisions for international projects. Finally, a pilot study is used to demonstrate and validate the approach.

INTRODUCTION

Background

International construction markets have changed dramatically during the last decade. Agreements such as the Uruguay Round in the General Agreement on Tariffs and Trade (GATT) system have fundamentally changed the structure of the construction industry. Globalization of construction markets is allowing more local firms to compete internationally (*Competing* 1993; *1997 International*; *Top* 1997). However, entry decisions for international construction markets are difficult due to the uncertainties associated with the international construction domain. International projects involve not only the uncertainties that arise on domestic construction projects, but also the complex risks that are particular to international transactions (Lee and Walters 1989; *Seminar* 1995). Failure to understand the political, economic, cultural, and legal project conditions can significantly affect the firms' strategic entry decisions associated with a new foreign market.

Because international projects are high risk, complex undertakings, only 19% of current U.S. top 400 contractors actively seek and conduct international contracts (*U.S.* 1998). These firms shared only 18.3% of all foreign contract awards during the period of 1994–97. Particularly, small and medium sized firms, those that ranked between 100 and 400 among the U.S. top 400 contractors, rarely participate in international construction markets. These small and medium sized firms control only 3.3% of the total U.S. firms' foreign market share. Furthermore, despite the complexity and difficulty of international market entry decisions, most construction firms have entered international markets based on personal intuition or previous experience, both of which are easily influenced by uncertainties and biases (Messner 1994).

The fundamental goal of this paper is to introduce a formal procedure for international market entry decisions, or more simply go/no-go decisions for the traditional competitive public sector projects, which are either financed by governments or funded by international agencies. The remainder of this paper focuses on the following three questions:

1. What are the essential risks associated with international construction projects?
2. What are the current approaches used to make go/no-go decisions for international construction projects?
3. What is the most appropriate approach for risk-based go/no-go decision formalism?

OVERVIEW OF INTERNATIONAL CONSTRUCTION

Changes to International Construction Markets

During the last decade, the world has witnessed the dramatic expansion of opportunities for contractors in international construction markets. Five critical changes have occurred that reduced barriers to international trade and expanded world construction markets. First, all signatory countries to the GATT system, about 116 countries, must open their domestic markets, including the construction service trade (Melvin 1995; *Trading* 1995). Additionally, 22 countries agreed to open their government procurement to foreign firms controlled by the GATT-Government Procurement Code. In procurement above the threshold of 5,000,000 special drawing rights [special drawing rights are international reserve assets created by the International Monetary Fund (IMF), and one special drawing right is approximately equivalent to $1.4 (Melvin 1995)] for construction services, 22 signatories to the code, including the United States, Canada, the European community, Japan, and South Korea, agreed to open their code covered procurements (DeGraaf 1995; Farabow 1995; *Trading* 1995; Mattoo 1996). As a result of these agreements, those signatory to the code eliminate discrimination against foreign firms and open their government procurement markets, including construction procurement.

Second, the development of regional Free Trade Blocs, such as the Asia Pacific Economy Corporation, the North America Free Trade Agreement, and the European Community, has had a profound impact on the construction industry by instituting free trade among member countries. The development of these blocs is likely to increase the construction trade and realign the construction industry by encouraging the formation of acquisitions and joint ventures, or opening new branch offices in the foreign country where they do business (Gross 1991).

Third, establishment of world standards like the International Standards Organization series has enhanced product acceptance and approval in international trade (Gross 1991; Yates 1996). As a result, construction firms are able to market standardized products in different countries.

Finally, rapid developments in telecommunication, travel, and other related industries have opened the international construction markets that were open only at a local level in the past (Moavenzadeh 1991). Moreover, new information tech-

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nology that provides fast data exchange at a low cost is bringing about new organization structures. It is no longer necessary to set up extensive local management offices, which significantly reduces overhead expenses.

Uncertainties: International Risks

As a consequence of these changes, more opportunities exist for contractors to enter international construction markets; however, international projects manifest more types of risks than do domestic projects. Often, contractors contemplating initial entry into international markets find these risks intimidating. For example, international construction is very sensitive to regional conditions such as currency devaluation, currency exchange restrictions, cultural differences, or changes in law or regulations. A number of authors have described the risks specific to international construction projects (Ashley and Bonner 1987; Demacopoulos 1989; Lee and Walters 1989; Messner 1994; *Seminar* 1995; Kalayjian 2000). The classification displayed in Fig. 1 partitions international construction risks into five categories. The scope of these risks supports the need for a formal methodology to incorporate the risks into a go/no-go decision.

Complexity of Entry Decisions for Overseas Projects

In addition to its risky nature, entering international construction markets is a highly integrated, complex decision. Decisions progress through the following three sequentially related stages: (1) identification of countries that are most favorable and least risky in which to do business; (2) selection of candidate projects within a candidate country; and (3) determination of whether to ‘‘go or not to go’’ on a specific project opportunity. However, despite the complex, risky nature of these decisions, existing tools and methods for evaluating international construction opportunities are fragmented and rudimentary. The following sections discuss current tools and approaches for making market entry decisions.

EXISTING APPROACHES RELATED TO ENTRY DECISIONS

Existing Methods

Country Risk Evaluations

Concern over international business risks has spawned the development of the country risk evaluation. Country risk can be defined as ‘‘either an outright loss or an unanticipated lower earnings stream in cross border business, caused by economic, financial or sociopolitical events or conditions in a particular country that are not under the control of a private enterprise or individual’’ (Newman 1981; Burton 1985).

Country risk, in general, involves war, revolution, prohibition of remittance, nationalization of projects, sudden change of tax rates, sudden changes in project contracts by the government, and other unanticipated goverment control (Tanaka 1984). The traditional method of assessment is a fully qualitative system that does not have a standard formula with respect to analytical span and degree of elaboration, and utilizes subjective rather than objective processes (Burton and Inoue 1983). The most common approach is a checklist system. The so-called country risk evaluating services, such as the Overseas Business Report, Overseas Political Insurance Corporation, and the Standard & Poor’s Sovereign Rating Service, focus on evaluating sovereign credit risks.

Political Risk Analysis

Traditional political analyses developed by the manufacturing industry for capital investment decisions do not adequately address contracting risk. As an alternative approach for the construction industry, Ashley and Bonner (1987) analyzed the political risk of international construction projects from a construction contractor’s perspective. They developed a political risk analysis approach that identified the primary sources of political risks and their resultant impacts on project cash flow and probable cost.

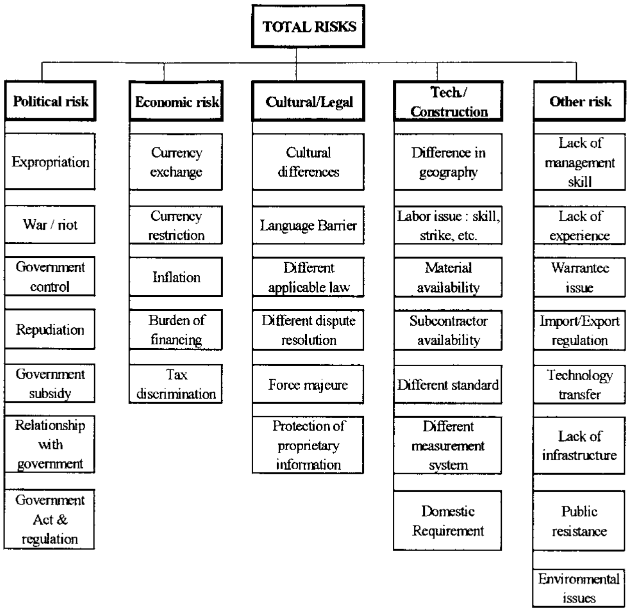


FIG. 1. Breakdown Structure of Risks (Revised from Various Sources)

Economic Risk Analysis

Another important factor is the economic risk associated with international construction projects. Changes in exchange rates under the floating economic condition have drastic impacts on the success of the projects. According to Tanaka (1984), there are two basic devices that provide risk management for foreign exchange risk—(1) diversifying received currencies; and (2) diversifying financing. For example, if a contractor is paid half in the local currency and half in U.S. dollars, economic exposure can be controlled within a certain range. In addition, if construction companies borrow money by splitting the loan into two or three different currencies, the borrower can minimize the exposure to any once currency. A study by Demacopoulos (1989) provided a conceptual and analytical framework for understanding and analyzing the economic and competitive aspect of foreign exchange exposure for construction firms competing in international construction markets. This approach extends the traditional cash flow analysis models to account for multiple currencies as a basis for the systematic evaluation of construction cost and revenue component exposures.

Project Appraisal Techniques

The World Bank and UNESCO developed risk analysis tools to analyze construction risks and to evaluate the feasibility and soundness of international projects from the lender’s standpoint (Pouliquen 1970; Reutlinger 1970; *Project* 1984). They proposed probability analysis, sensitivity analysis, and simulation methods as risk analysis techniques.

Portfolio Management

Another project selection method is the use of the portfolio management techniques (Vergara and Boyer 1977; Kangari and Boyer 1981). The basic concept of portfolio management is to reduce the overall risks associated with a portfolio of projects through diversification. If each project investment has a given risk and return, then by combining investments where the risks are not closely correlated, variance reduction and a lower risk level can result.

Bid/No-Bid Models

Ahmad (1990) conducted a survey of the different factors that influenced the bid/no-bid decision for an individual project. Ahmad organized bid/no-bid factors into four main categories—job, firm, market, and resources. Ahmad proposed an additive multiattribute hierarchy for determining the desirability of a project.

Information Framework/Process Models

Messner (1994) presented an exploratory investigation of the information framework for evaluating international construction projects. Messner identified five generic categories of information required to evaluate the project effectively—organization, commitment, process, environment (including related risk variables), and facilities. In addition, he proposed a process model to show the decision flows needed to decide whether to pursue a project opportunity.

Shortcomings of Existing Methods

Existing tools for international market entry decisions focus mainly on specific fragmented areas, such as political or economic exchange risk (Ashley and Bonner 1987; Demacopoulos 1989). Commercial country risk evaluating services provide useful information for overseas investments, but do not yet satisfy the quality and accuracy of information necessary for international construction markets. Portfolio management does not focus on a specific market that construction firms would like to enter. Existing bid/no-bid models are primarily designed for domestic construction projects. Finally, the information framework analysis process model developed by Messner (1994) focuses on qualitative tools and does not provide a computational methodology to evaluate the project conditions.

FORMALIZING A GO/NO-GO MODEL

Decision-Making Approach

Based on shortcomings of existing tools and the complexity of the decision context, this paper describes a risk-based, analytical methodology for go/no-go decisions. There are two distinct types of decision-making theories—the ‘‘normative decision theory’’ and the ‘‘descriptive cognitive theory’’ (Carroll and Johnson 1990; Noll and Krier 1990). Normative decision theory attempts to analyze decision tasks to prescribe the optimal way to behave (Von Neumann and Morgenstern 1944). On the other hand, descriptive decision theorists attempt to describe how decisions are actually made. Descriptive decision theorists argue that actual decisions consistently diverge from the rational, normative models due to errors and biases (Kahneman et al. 1982; Bazerman 1986; Dawes 1988; March 1988). This go/no-go decision model is fundamentally a risk-based, normative model. Further, it is predicated on the assumption that decision makers want to make optimal decisions, but are unable to because of the lack of knowledge or

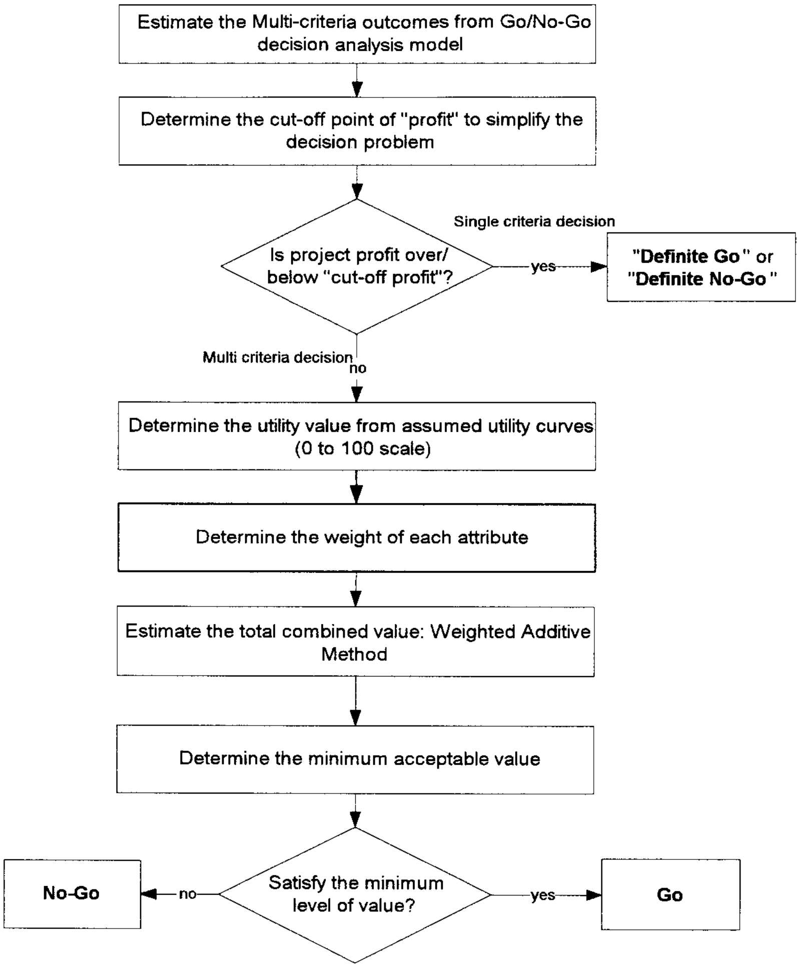


FIG. 2. Go/No-Go Decision Process Model

cognitive overload in the face of a complex, risky situation (Carroll and Johnson 1990).

The risk-based, go/no-go decision is conceptualized as one that is decided primarily on a project's profit criterion. If a project fails to satisfy the profitability criterion, other potential benefits of pursuing the project are considered, as shown in Fig. 2. In this process, the decision maker sets an absolute goal on ''project profitability,'' above which the decision is ''definitely go.'' The decision maker also sets a lower profitability limit to fix the ''definitely no-go'' decision. If project profitability lies between the profitability limits, the decision is made based on criteria considering both project profitability and ''other project benefits.''

Selection of Uncertainty Reasoning Tool for Assessing Risks

Current Uncertainty Reasoning Tools

Selecting an appropriate technique for evaluating the uncertainty associated with a specific go/no-go decision is an important aspect of model development. Historically, the mathematical theory of probability has been the most widely used uncertainty reasoning tool. In addition to probability theory, there are other numerical calculi for the explicit representation of uncertainty or techniques to manage uncertainty using logic or other symbolic formalism (Shafer and Pearl 1990). Table 1 compares the advantages and disadvantages of several common uncertainty reasoning tools as suggested by many authors (Cooper and Chapman 1987; Diekmann et al. 1988; Flanagan and Norman 1993; Takayuki 1994).

Most of these uncertainty reasoning techniques are data intensive, they require significant data collection, formulation of mathematical representations, assessment of conditional probabilities, or definition of probability density functions. However, uncertainties involved in international construction are difficult to assess using traditional tools such as probability theory and influence diagrams because the data required for the model are judgmentally intensive and scarce, unavailable, or very expensive to collect. Additionally, the go/no-go decision model entails highly complicated relationships among risk variables, so it is very hard to assess the accurate conditional probability relationship between variables. For these reasons, all of the traditional uncertainty reasoning methods were rejected for this application. Instead, we adopted the cross-impact analysis (CIA) method for this go/no-go application.

CIA Method As Uncertainty Reasoning Tool

The CIA method is a technique specifically designed to predict future events by capturing the interactions among variables. The original CIA method was developed by Gordon and Hayward (1968) as an attempt to take into account impacts among separate events. In the CIA method, each variable is described by an initial probability and the interconnections between these variables are modeled by cross-impact relationships. The basic cross-impact relationship between two variables describes how the initial probability of a conditional variable will be inhibited or enhanced if a conditioning variable occurs.

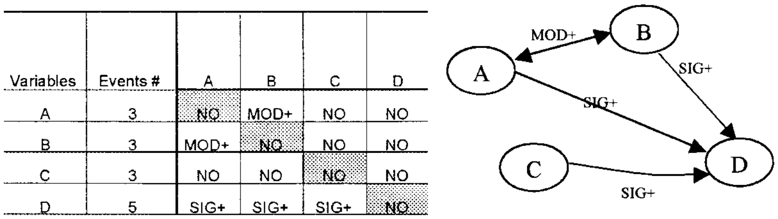
Originally, the computational mechanism for determining the impact of A on a posterior probability of B ignored the strength of the relationships among the variables (Gordon and Hayward 1968). Subsequently, researchers have proposed more rigorous mechanisms to calculate the posterior probabilities. For example, Honton et al. (1985) adopted a categorical approach to estimate the posterior probability by asking for the direction and strength of the impacts. An index number between -3 and $+3$ is used to express the cross-impact relationship, and then this number is used to calculate the impact using an analytical expression with a more rigorous mathematical formulation. Alarcon (1992) developed the concept of cross-impact relation patterns in order to simplify the knowledge acquisition demands of the traditional CIA methods. The cross-impact relation patterns between variable pairs are classified as follows: (1) SIG−: significantly in the opposite direction; (2) MOD−: moderately in the opposite direction; (3) SLI−: slightly in the opposite direction; (4) SIG+: significantly in the same direction; (5) MOD+: moderately in the same direction; and (6) SLI+: slightly in the same direction.

Based on these CIA relation patterns, the posterior probability can be predicted throughout the series of analytical processes (a brief description of the CIA analysis methodology is presented in Appendix I). The general steps for this CIA method are as follows: (1) Define variables to be included in the analysis; (2) determine the initial probability of each variable; (3) judge the CIA relations for each variable pair; (4) perform the cross-impact calculations by Monte Carlo simulation; and (5) evaluate the posterior probability to forecast future events.

The CIA method is a powerful technique to deal with ill-defined uncertainty and circumstances that are judgmentally intensive but data poor. In addition, the CIA method generates various scenarios that are used to analyze the sensitivity of

TABLE 1. Comparisons of Uncertainty Reasoning Tools

Tools	Advantages	Disadvantages
Intuition-based analysis	Applies to simple and general situations	Easily influenced by information uncertainty and biases; ineffective in solving complex problems
Statistical approach	Used for incorporating history data in risk analysis	Requires tremendous effort in data collection
Decision tree	Used to calculate correlated decision and risk variable sequences	Too much complexity in the form of correlated variables
Simulation	Assesses risk variable through repeated iterations; very good at handling complexity	Needs a mathematical model (i.e., cost or schedule formula); needs to define probability density function for each variable
Analytical methods	Attractive under simple conditions because it can develop quantitative evaluation tools; output can be readily interpreted	Not applicable to complex problems; need multiple factors to reflect a realistic situation
Influence diagram	Good at modeling conditional probability relationship among variables; useful when handling model complexity	Requires detailed representation of the relationships
Neural network	Superior convergence capability in the case of a large amount of historical data sets	Highly sensitive to data set; requires a large amount of historical data



Variables	Events #	A	B	C	D
A	3	NO	MOD+	NO	NO
B	3	MOD+	NO	NO	NO
C	3	NO	NO	NO	NO
D	5	SIG+	SIG+	SIG+	NO

FIG. 3. CIA Strength Relationships

TABLE 2. Defining Variables

Variable	Variable's name	Event	Event's name	Initial probability	Outcome values
A	Political condition	A_1	Bad	0.7	—
		A_2	Average	0.2	—
		A_3	Good	0.1	—
B	Economic condition	B_1	Bad	0.8	—
		B_2	Average	0.1	—
		B_3	Good	0.1	—
C	Technological ability	C_1	Bad	0.6	—
		C_2	Average	0.3	—
		C_3	Good	0.1	—
D	Project cost	D_1	Really bad	0.1	125
		D_2	Bad	0.25	105
		D_3	Average	0.3	100
		D_4	Good	0.25	95
		D_5	Really high	0.1	75

variables and produces probabilistic, multicriterion outputs. Accordingly, the CIA method is most effective in the following circumstances:

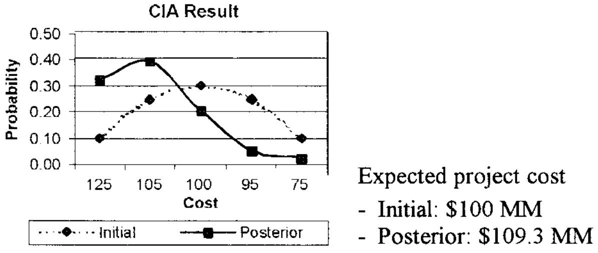
1. When the model involves very complex and unclear relationships among variables. The CIA method is excellent at integrating political, economic, and technological factors for which it is very difficult to identify accurate interrelationships.
2. When the data required for the model are scarce, unavailable, or very expensive to collect. It is easier to elicit subjective probability information using the CIA categorical approach rather than a standard probability approach.
3. When the model involves various possible decision alternatives. The CIA method can show the results of various possible decision alternatives by evaluating alternative scenarios when a decision maker cannot ascertain that a single solution is optimal.

Illustrative Example

To illustrate the five steps noted earlier, suppose that four variables affect the cost of a candidate go/no-go project, as shown in Table 2. An initial probability is assigned to each event's state. First, assume that the most likely project cost is U.S. $100 million. Further assume that the worst and the best case costs are U.S. $125 million (initial probability = 0.1) and U.S. $75 million (initial probability = 0.1), respectively.

CIA relationships between variables are then developed. Each relationship indicates that if the predecessor variable occurs, the successor variable will be affected according to the nature of the CIA relationship. For example, as shown in Fig. 3, if the political condition (*A*) would be bad, the project cost (*D*) could be affected significantly in the same (bad) direction (SIG+ relationship).

After determining the initial marginal probabilities for each variable's states and their respective CIA relationships, the posterior probabilities on project cost are calculated. Fig. 4 is a comparison of the prior probability of cost and the posterior probability of cost. In this simple model, the average project cost will increase by 9% (initial U.S. $100 million to posterior U.S. $109.3 million) due to relatively bad conditions in the political and the economic environments.



Expected project cost
- Initial: $100 MM
- Posterior: $109.3 MM

FIG. 4. Summary of CIA Program Output

DEVELOPMENT OF GO/NO-GO DECISION-MAKING MODEL

CIA Cause-and-Effect Relationships Model

A comprehensive CIA-based go/no-go model was developed using knowledge gained from a thorough literature review and the input of several international construction procurement experts; the model is shown in Fig. 5. This model includes a total of 32 variables that are classified in Fig. 1.

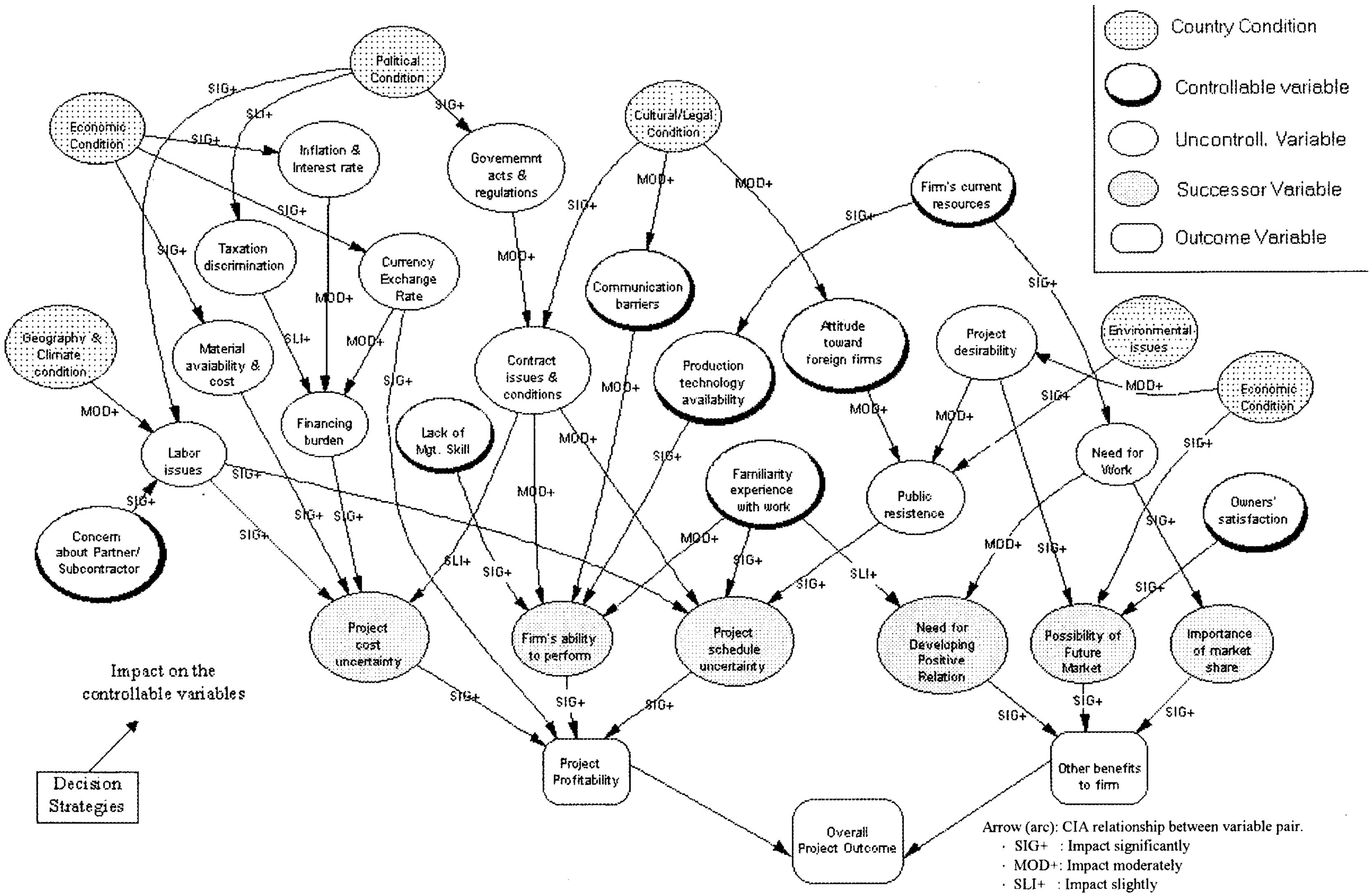
It helps to understand this very complex model by conceptualizing the model's variables as belonging to one of five groups, as shown in Fig. 6. One set of variables, "country conditions," represents each country's unique, a priori atmosphere for conducting trade. The country conditions are

1. Cultural and legal conditions
2. Political conditions
3. Economic conditions
4. Geography and climate conditions
5. Environmental conditions

Each of these overlying conditions impacts (in the cross-impact sense) several other variables. For example, a country's cultural and legal conditions impact its "attitude toward foreign firms"and its "contract issues and conditions." Likewise, the economic conditions impact "inflation and interest rates" and "material cost and availability." Country conditions are relatively fixed for any given country. However, over the life cycle of a project, economic, cultural, and political conditions can change; therefore, they are treated as being uncertain.

A second set of variables represents the construction contractor's decision strategies. Specifically, the contractor's resources, experience, management skill, owner relationships, and strategic partnerships are defined as strategic variables. "Contractor's strategic" variables are presumed to be controllable, in that a contractor can hire more talented or experienced people, change strategic alliances, or commit more resources. Country condition variables and "decision strategies" form the initial conditions for the go/no-go analysis.

The third and largest set of variables is impacted by either the country conditions or the decision strategies. These are called intermediate variables. The intermediate variables are



Arrow (arc): CIA relationship between variable pair.
- SIG+ : Impact significantly
- MOD+: Impact moderately
- SLI+ : Impact slightly

FIG. 5. CIA-Based Go-No-Go Decision Model

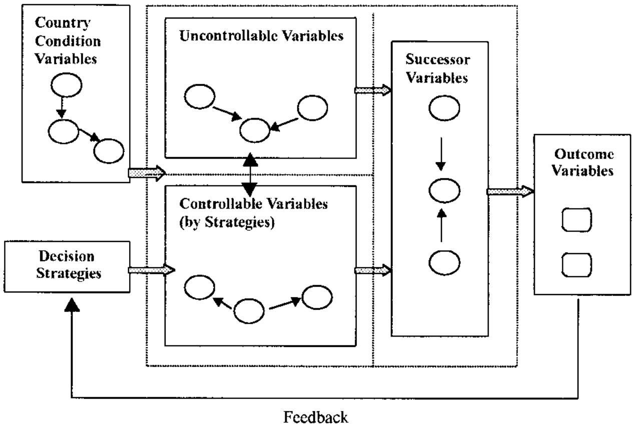


FIG. 6. Conceptual Components of Go/No-Go Decision Model

divided into those that are impacted by the contractor decision strategies (controllable) and those that are not (uncontrollable). These variables provide the means to propagate the impacts (indeed, the cross impacts) of the initial conditions (country condition and contractor's decision strategies) to the model results.

The fourth type of variable reflects the likely outcomes of the project, a successor variable set for producing the final results. There are three project outcomes—namely, project cost uncertainty, project schedule uncertainty, and contractor's ability to perform the project. In addition, there are three corporate outcomes—namely, potential for future work, importance of developing market share, and importance of developing a relationship with the client.

The fifth set of variables is the outcome variables by which the go/no-go decision is made. There are two outcome variables—the "project profitability" outcome and the "other benefits" outcome. The project profitability outcome is a combination of the previously mentioned successor variables (cost, schedule, and ability to perform). The other benefits outcome is a combination of the previously mentioned corporate outcomes (client relationship, future work, and market share).

In practice, one employs the model by defining initial country conditions, the initial contractor decision strategies, and the appropriate cross-impact relationships for the model. Using the cross-impact method, the initial and strategic conditions are propagated through the model to the outcome variables. The value of the outcome variables provides the normative metric by which the go/no-go decision is made.

In particular, the CIA-based model is closely correlated to the design of corporate strategic planning. This model includes long-term outcomes such as gaining future markets, a contractor's need for work, developing new relationships, etc., in addition to a short-term profit. As a result, the corporate strategies can be designed and evaluated analytically to mitigate or avoid the relevant risks. For example, if a contractor selects "alliance strategies" to develop a new organization, he/she can partially or fully control certain types of risk variables (i.e., partner/subcontractor's concern, lack of management skill, production technology availability, and familiarity with work). To evaluate the effectiveness of an alliance strategy, the decision maker would suitably alter the initial conditions and strength relationship of the CIA model. Based on the trial results, a decision maker can evaluate which alternative corporate strategies are the most effective in improving project outcomes.

PILOT CASE STUDY EXPERIMENT

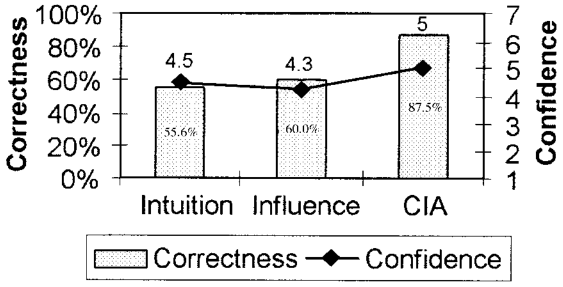


FIG. 7. Results of Pilot Case Experiment

To determine whether this model would help decision makers handle the complexity and uncertainty associated with go/no-go decisions, we conducted a "pilot test" of the model. Among the conventional uncertainty reasoning tools (Table 1), intuition-based techniques and influence diagramming were adopted for comparison with a CIA-based model because they are widely used methods in risk analysis and are applicable to this research problem domain. Twenty-four graduate students enrolled in an "engineering risk and decision analysis" class at the University of Colorado participated in this study. A hypothetical international project was assigned randomly to three groups, which consist of the "intuition group," the "influence diagram group," and the "CIA-based go/no-go model group." As indicated by the group names, the intuition group used intuition combined with rudimentary financial analysis to make the go/no-go decision. The influence diagram group used standard decision theoretic methods based on probability theory. The CIA group used the cross-impact model to make the go/no-go decisions.

The project used in the study is a U.S. $100,000,000 hydropower dam construction in Laos. It was modified to provide high profitability and other potential benefits such as high possibility for future projects. Independent risk and economic analyses indicated a "go" decision as a correct decision. The suggested correct decision was veiled from all participants in order to avoid any potential biases. Each participant was asked to make a go/no-go decision and respond to several questions that measured how well the different decision tools affected (1) decision correctness (%); and (2) decision confidence in their final decisions (1–7 scale). The correctness of the decisions was counted as the number of right decisions out of the subtotal of each group. The decision confidence level was measured using a qualitative index number ranging from 1 (not confident) to 7 (very confident). Each participant's result was compared with the correct decision. Fig. 7 summarizes the findings from the pilot case study.

As shown in Fig. 7, intuition based decision makers are confounded by the complexity of the circumstances. As a result, only 55.6% of the decisions made by the intuition group were correct. Likewise, only 60% of the decisions made by the group that used the influence diagram were correct. By contrast, 87.5% of the decisions made by the "CIA model" group were correct.

There were numerous factors that caused the subjects to make incorrect decisions. In the case of the intuition group, the go/no-go decision was influenced by the complexities and several biases, such as (1) focusing only on negative factors such as unfavorable political/economic risks, government control, and competitive bid type rather than other various positive aspects; (2) ignoring some relevant factors such as the possibility of a future market and the firm's need for entering overseas markets; (3) simply comparing the number of external and internal risks; and (4) adopting an extremely risk-averse attitude. In the case of the influence diagram group, the assessment of conditional probabilistic relationships and the assignment of outcome values required for the influence diagram were difficult for the decision makers. On the other hand, only one subject out of eight in the CIA model group made a wrong decision, mainly due to the error in judging the CIA relationships by making too many unnecessary redundant CIA relationships. In addition, the CIA group experienced higher levels of confidence in their decisions than did either of the other decision-making groups. A more complete description of the validation testing for the go/no-go model is the subject of a future paper.

SUMMARY AND CONCLUSIONS

Among the several decision analysis approaches, the CIA method was selected for this decision context because

1. The CIA method is effective for describing subjective conditional relationships and outcome values that have imprecise relationships between variables.
2. The CIA method fits well with the way experts are able to express their expertise and to represent their subjective knowledge required for the model.
3. The CIA method allows the decision maker to test different combinations of go strategies, and predict expected profitability and other project benefits.
4. The CIA method provides a powerful computational capability to predict future scenarios and to evaluate the sensitivity of each variable under the various decision options.

In an elementary pilot study, the CIA method, compared to the other previously mentioned methods and techniques, yielded decisions that were more accurate and decision makers who were more confident in their judgments. Encouraged by the results of this pilot study, we intend to focus our future methodological research on extensions of the current CIA model and improvement of the modeling platform. Future procedural research will concentrate on expert knowledge elicitation and model validation through more extensive full-scale experimental case studies by industry participants. Additionally, in recent years, research has been carried out to study issues of risk management for international build-operate-transfer (BOT) projects (McCarthy and Tiong 1991; Donnelly 1997; Nielsen 1997; Ock 1998). The CIA-based model will be extended to these related fields, such as modeling for international design/build projects, international BOT projects, and international private sectors.

APPENDIX I. CIA COMPUTATIONAL EXAMPLE

Suppose that two variables, *A* and *B* in Fig. 8, consist of two possible event states. Each variable has an initial probability, as shown in Table 3. In this simple explanation of CIA computation, variable *A* influences another variable, *B*. Therefore, it is assumed that the cross-impact matrix is judged as shown in Table 4.

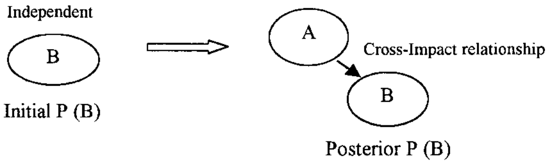


FIG. 8. Simple Example of Two Variables

TABLE 3. Information of Variables

Variable	Event	Initial probability
A	A_1	0.5
	A_2	0.5
B	B_1	0.4
	B_2	0.6

TABLE 4. Cross-Impact Relationship Table

		A		*B*	
Variable	Event	A_1	A_2	B_1	B_2
A	A_1	—	—	0	0
	A_2	—	—	0	0
B	B_1	3	−3	—	—
	B_2	−3	3	—	—

Note: If event A_1 occurs, events B_1 and B_2 will be impacted significantly in the positive and negative direction, respectively. Additionally, 3 = significant increase, 2 = moderate increase, 1 = slight increase, and 0 = no effect.

The next step is to calculate the posterior probability of variable *B*. Suppose that event A_1 were to occur as a result of Monte-Carlo random sampling. The probability of variable *B* is adjusted according to the following analytical formula justified by Honton et al. (1985):

$$\therefore \text{ Posterior } P_n = \frac{\text{Initial } P_n \times C.V}{1 - \text{Initial } P_n + (\text{Initial } P_n * \text{C.V})}$$

where $C.V$(coefficient value) = $|\text{cross-impact index}| + 1$ if index ≥ 0 and $1|/\text{cross-impact index}| + 1$ if index < 0.

$$-\text{Posterior } P(\text{B}_1) = \frac{0.4 \times 4}{1 - 0.4 + (0.4 * 4)} = 0.73$$

$$-\text{Posterior } P(\text{B}_2) = \frac{0.6 \times 0.25}{1 - 0.6 + (0.6 * 0.25)} = 0.27$$

If event A_2 were to occur, the probability of variable *B* is influenced in a similar way. The above steps are repeated a large amount of times until an accepted error is reached (Monte Carlo simulation). In the above example, both variable *A* and variable *B* are described by the initial probabilities. The posterior probability of variable *B* is said to be posterior probability (after the fact) due to the cross-impact effect of variable *A*. Instead of conditional relationships between variables, the cross-impact matrix table describes the relationship between variables.

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