ESTIMATING USING RISK ANALYSIS FOR CONSTRUCTION

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Risk analysis in construction is becoming important as competition, project size and complexity increase. Traditional risk analysis relies on rules of thumb. While this method works, it is not scientific. Research findings by cognitive psychologists revealed that subjective judgments by human beings are sometimes fallacious and erroneous. Empirical studies with construction professionals, i.e. context-specific subjects making decisions on context-specific tasks, showed that such judgments were not as fallacious as is suggested. The principles and techniques of risk management for project cost and time are now quite well known. Our professional duty of care requires that we are familiar with the limitations of any technique we use in practice. Hence, this paper aims at (i) highlighting the weaknesses of current approaches to risk management; (ii) focusing on the role of the decision maker as human being in a social and corporate context by carrying out experimental studies of patterns of risk perceptions; and (iii) model these risk perceptions by a fuzzy system; and (iv) suggesting some simple, practical approaches which will help to reduce the negative effects of human biases in the risk management of construction projects.

Keywords: Estimating using risk analysis, fuzzy sets theory, risk.

INTRODUCTION

Tendering for projects is still the major means by which contractors in the construction industry obtain work. With the advent of alternative procurement methods such as management contracting and design and build, it has been stressed that price is not the major factor considered by the client. However, from the point of view of the contractor, a business entity, price is still a sensitive factor. At least it forms the floor in the process of negotiation.

Risk treatment in construction has traditionally focused on risk distribution between the owner and contractor during the tendering stage by imposing contractual clauses. The main contractor, invariably, does the same to its sub contractors and suppliers. This distribution is generally one sided and assumes that the contractor should assume responsibility for most of the risks associated with the project. There has been a growth in the literature to address the problem of systematically managing risks involved in construction projects.

RISK MANAGEMENT IN CONSTRUCTION

The term risk management can be defined as the formal orderly process for systematically identifying, analyzing, and responding to risk events throughout the life of a project to obtain the optimum degree of risk elimination or control (Al-Bahar, 1988). There are many definitions to the term risk. Boodman (1977) defines it as the variation in possible outcomes that exist in nature in a given situation. Faber (1979)

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views it as the likelihood of the occurrence of a definite event or combination of events which occur to the detriment of the project. Merrett and Sykes (1973) define it as a situation where there exists no certain knowledge of its outcome. Hertz and Thomas (1983) refer risk as a lack of predictability about structure, outcome or consequences in a decision or planning situation. Lifson and Shaifer (1982) say that risk is the uncertainty associated with estimates of outcomes which means that there is a chance that results could be better than expected as well as worse than expected. Risk and uncertainty are usually synonymous although some authors insist to distinguish between the two by defining risk as quantifiable, that is the probability of its occurring is known; whereas uncertainty is unquantifiable meaning that the probability of the possible outcomes are not known.

The effective management of risk is often a key to successful completion of projects on time and at a profit. Risk management has been regarded as a 3-stage exercise, namely, risk identification, risk analysis and response management (Flanagan and Stevens, 1990).

CURRENT PRACTICE OF RISK MANAGEMENT IN CONSTRUCTION

The purpose of risk analysis of estimates is to take into account the inherent uncertainty of the costs (or duration) of individual activities or elements within a project when accessing the anticipated final cost of a particular scheme. This enables the project director to evaluate the likelihood of meeting budget or time limits. Risk analysis has always been used synonymous with probabilistic analysis in that the Bayesian type statistical inference is used (Flanagan and Stevens, 1990). It is argued that the construction industry featuring a humanistic system in which this kind of probabilistic analysis is not necessarily appropriate. On the one hand, the harsh assumptions behind Bayesian statistics cannot easily be met. On the other hand, heuristics are still commonly employed. Subjective judgments predominate the whole risk analysis process. It is therefore necessary to explore new directions for risk analysis in construction. Fuzzy sets theory is introduced as an alternative approach. The feasibility of using fuzzy sets theory to building an expert system for risk analysis will be explored.

Recent research shows that no company used any computer programmes to determine bid price. They rely on the memory and knowledge of their managers (Hillebrandt and Cannon, 1990). To an extent this explains the uncertain environment contractors are facing and the reliance on the expertise of the human mind. It also reveals the , characteristics of a humanistic system in construction.

This kind of judgment adopted by most estimators has been termed subjective judgments in that they *estimate* the probability of occurrence of an event not by quantitative methods, i.e. basing on historical data and using proper statistical inference to reach a conclusion, but by some sort of qualitative methods derived from experience and heuristics.

The Inappropriateness of Bayesian Statistics

To utilize the vigorous treatment of statistical theory on uncertainties as found in a mechanistic system precise description of the probabilities is necessary. However, without the support of reliable historical data, subjective judgments have been made of the probabilities of events. This entails the use of such parameters as means and standard deviations. By far the use of these parameters is too complicated for the construction industry. Worse still, complicated parameters may introduce more human errors based on misunderstanding or misinterpretation of the parameter provisions.

Bayesian statistics have been regarded as the normative theory for making probability calculations. However, the Bayesian approach is a mechanistic system and requires harsh assumptions. It requires that the events to be combined in a Bayesian function be mutually exclusive, exhaustive, and conditionally independent. In fact, Szolovits and Pauker (1978) suggests that the conditional independence assumption almost never holds in their domain, i.e. medical diagnosis. In construction, in evaluating the probability of delaying a project, there are so many causes that they can't be exhaustively listed, not to mention their mutual dependence and correlation. For example, in a simple 3-activity (in a simple project of 3 sequential activities) project, if the evaluated probability of delay of each is 0.2 then the probability of completing on time is 0.8. By Bayesian approach, the probability of delaying the project is 1-0.83=0.488. This is based on the assumption that the three activities are mutually exclusive and independent. In reality, however, if the time required for activity 1 is lengthened, it can probably lengthen the time for activity 2 and 3. This will then make the probability of delaying the project much higher. On the other hand, having activity 1 delayed, the site management can increase resources for activities 2 and 3 to catch up with the time (at a higher cost, of course) thereby reducing the probability of delay. This kind of judgment cannot be reflected in the Bayesian calculations. The application of Bayesian calculations is used just because it is the normative theory and it can give a .precise answer. The user always yields to the underlying assumptions unconsciously. The more complex the situation, the more difficult to apply the Bayesian approach successfully; but the more precise the figure can be given (to many decimal digits).

Research done by cognitive psychologists on 'subjective' judgments shows that these judgments are flawed and erroneous. They base their arguments on the normative Bayesian theory.

Dispute has arisen since the last decade on their arguments. On the one hand, it has been contested by some philosophers. On the other hand, some artificial intelligence (AI) researchers (Cohen, 1985) have also queried the usefulness of the Bayesian approach in the area of expert systems. Shortcomings of the Bayesian approach are summarised as:

1. The assumptions involved in deriving a Bayesian combining function, i.e. mutually exclusive and exhaustive hypotheses and conditional independence of evidence in a hypothesis, do not always hold. Some authors suggest that the conditional independence assumption almost never holds in some domains (Cohen, 1985:31). An example in a construction project is that a delay in the critical activity will not only affect the duration of the project but also the total cost; but a delay in non-critical one may only affect the cost of that activity (or it will have no effect at all).
2. The Bayesian view of probability does not allow one to distinguish uncertainty from ignorance, i.e. one cannot tell whether a degree of belief was directly calculated from evidence, or indirectly inferred from an absence of evidence (Cohen, 1985). By applying Bayes' formula, one has taken a tool meant to apply to situations in which uncertainty is based on randomness and applied it to a situation in which uncertainty comes from ignorance (Borden, 1987: 580-590).

3. The single degree of belief is represented by a point estimate so it is difficult to verify its accuracy ,however precise it may be (Cohen, 1985).

The Use of Heuristics

Heuristics is a word derived from the Greek word *heuriskein* meaning to discover (Daellenbach *et al.*, 1983). Heuristic problem solving is not a solution method in the sense that the simplex method of linear programming is, but rather it is a philosophy of, or strategy for, seeking out a method or methods that might produce a solution to a particular problem. Heuristic problem solving involves inventing a set of rules that will aid in the discovery of one or more satisfactory solutions to a specific problem. The emphasis is on 'satifisfrying', i.e. being satisfactory or acceptable. Optimality is never guaranteed. Heuristic methods are based on inductive inferences related to human characteristics of problem solving, such as creativity, insight, intuition, and learning. A particular heuristic is followed because it promises, intuitively or from experience, to help in the search for an acceptable solution, and if in the process a better rule is discovered, then the old one is discarded. So while heuristic problem solving involves the use of currently accepted rules, it may also involve a search for even better rules to replace them.

The Baconian approach to assessing likelihood is different. Baconian functions grade probability *by the extent to which* all relevant facts are specified in the evidence, therefore they judge from provability to non-provability, as found in an incomplete system. This is directly opposite to the Pascalian approach to judge from provability to dis-provability .

The Baconian approach does not have the properties of complement and negation as found in Pascalian approach. For example, if A is quite irrelevant to B then it is quite normal that both p_l(B|IA) and p_l(not –B|A) have zero-grade inductive reliability (as opposed to p_l(B|A)=1-p_1(not-B|A)). For example, an increase in crude oil price may have significant effect on the inflation rate in the UK but it may have little effect on the building cost index because crude oil price and building cost index is more remotely linked as compared to the inflation rate. So p(Building cost will increase | Crude oil price increased) = 0 and p(Building cost will NOT increase | Crude oil price increased) = 0 can co-exist.

The Construction Industry: A Humanistic System

A humanistic system is a non-mechanistic system in which human behaviour plays a major role. A single individual and his thought processes may also be viewed as a humanistic system (Zadeh, 1965). The high standards of precision which prevail in mathematics, physics, chemistry, engineering and other 'hard' sciences stand in sharp contrast to the imprecision which pervades much of sociology, psychology, political science, history, philosophy, linguistics, art and related fields. This marked difference in the standards of precision is due to the fact that the 'hard' sciences are concerned in the main with the relatively simple mechanistic systems whose behaviour can be described in quantitative terms, whereas the 'soft' sciences deal primarily with the much more complex non-mechanistic system in which human judgment, perception and emotions play the dominant role.

A humanistic system is therefore a system which mostly depends on human actions. As Hillebrandt describes, in the tendering stage, the contractor needs to gauge a price for a project not yet built, for which he may not have seen the detailed drawings, on a site of which he may have no knowledge, and with a labour work force not yet organized (Hillebrandt and Cannon, 1990).

Projects form the basis of business transactions in the construction industry; therefore project management plays an important part in the design and construction activities, although this is not a unique feature of the construction industry. A project by itself has the character of a new and unique venture (Seiler, 1990). Experiences gained from finished projects cannot be fully transferred to new ones. The information at hand is often conflicting, inconsistent and incomplete. There are routine processes in projects with a high degree of novelty which are handled with a known and mastered technique; but in general the automation of generating, surveying and controlling working procedures could be more difficult than with conventional management tasks (without project characteristics).

Moreover, a construction project is an engagement over different points in time of several organizations such as consultants, contractors, sub-contractors and suppliers, with a client system that is itself organizationally complex. The management of a construction project from inception to completion can be perceived as a function of a temporary multi-organization (TMO) comprising relevant parts of these component organizations (Cherns and Bryants, 1984). The TMO is indeed a device for handling uncertainty, the structure and mode of functioning of which will depend on the nature of the uncertainties and will change over time as the focus of uncertainty shifts during the course of the project. The actual performance of the TMO is, however, determined more by the managerial capabilities of its component organizations and their co-ordination than by the form of the contract being adopted.

Further, it is generally recognized that construction activity is unique on each site in the sense that incidents do not always repeat as they do in factory production, e.g. ground conditions, labour productivity, and subcontractor competency. One has to distinguish between project management and conventional management. Managing construction work can be thought of as typical project management whereas managing a factory can be thought as typical conventional management. The former is characterized by less routines and more novelty. In contrast products manufactured in a mass scale in a factory in which the failure rates are statistically well documented, the case in the construction industry is seldom the same. The one-off nature of most construction project, the interaction of the many (humanistic) parties such as client and contractor, designers and consultants, suppliers and subcontractors, has made the system highly complex.

There is a lack of statistical data with respect to the components of the uncertainties as well. Actually, under a humanistic system, statistical data can hardly be collected, unless a very broad definition of a datum is used, as is found in the traditional bidding models like the Friedman model {Friedman, 1956). In the Friedman model, the competitors' bids are collected and analyzed statistically. However, the bid is built up from so many factors, especially subjective and humanistic factors, that the data can only give an extremely blurred and highly generalized picture of the bid environment. This low level in the information structure in the construction industry results in greater uncertainties regarding the probabilities of the outcomes.

In a mechanistic system such as a production line in a factory, there is an abundant quantity of the statistical data showing, say, the failure rate. The behaviour of the system under certain conditions in a mechanistic system is much more stable. However, in a humanistic system, even if a statistical datum is available, it is less convincing because of the wide variety of causes to an event. Humanistic systems also often deal with much more complex situations in which human judgment, perception and emotions play the dominant role.

As Mason and Mitroff (1981) call it, decision making in project management is a 'wicked problem' which has the properties of (i) interconnectedness, (ii) complicatedness; (iii) uncertainty; (iv) ambiguity; (v) conflict; and (vi) societal constraints. Regardless of the various models which intend to help contractors make appropriate decisions in the bidding environment, most contractors have developed a series of rules of thumb when dealing with risk. These rules generally rely on the contractor's experience and judgment, rather than on factual data.

Bias in Estimating

Successful application of a risk management system depends on two fundamental factors, that is, (i) the correct and appropriate identification of risks, and (ii) the accurate forecast of cost estimates. Little research has been done on contractor's estimating accuracy. Actually, it is very difficult to define the accuracy of a contractor's estimate. First, there is no objective 'answer'. Secondly, the tender price has been blended with an important element, business decision, in addition to the pure estimate as such. But research done with professional quantity surveyors show that it is the skilled interpretation and intuitive assessment of the available data that produces the most accurate advice (Skitmore, 1989). Because of these, the notion of bias has been introduced to evaluate the estimates. However, it should be noted that there is not a consensus in the literature on bias. The commonly held assumptions of systematic error and bias which flow directly from a large body of the literature on psychology (Tversky and Kahneman, 1974) have been criticized by, among others Cohen (1981, 1986) and Hogarth (1981). Skitmore et al. (1990) defined bias in terms of the relationship between the value of the contract price forecast and the value of the lowest tender. They have devised 3 measures of bias; namely, raw difference, percentage difference and log difference. These are dependent variables and are affected by such factors as the target contract, the forecast technique used, the information used, feedback, and the forecaster in the process of forecasting.

A LINGUISTIC APPROACH TO EXPRESSING UNCERTAINTIES

Complexity and precision bear an inverse relation to one another in the sense that, as the complexity of a problem increases, the possibility of analyzing it in precise terms diminishes (Zadeh, 1965). As the complexity of the system increases, the ability to make precise and yet significant statements about its behaviour decreases. This trade-off between precision and significance continues until a threshold is reached beyond which complexity, precision and significance can no longer coexist.

If the probability of an event is not known with precision, that is, with such descriptive parameters as mean and standard deviation, then it may be characterised linguistically as, say, quite likely, not very likely, highly unlikely, and so on. It is quite natural and has indeed always been used by professionals not only in construction, but also in medicine, political science and law, etc. The essence of this linguistic approach is that is sacrifices precision to gain significance, thereby making it possible to analyze in an approximate manner those humanistic as well as mechanistic systems which are too complex for the application of classical techniques.

One inherent characteristic of linguistic description is imprecision because it depends upon the human element. And linguistic expression often causes, first, ambiguity, i.e. the association with a given object of a number of meanings. An example is 'the design is expensive' which can mean 'the design fee is high' or 'the materials specified in the design is expensive' or 'the shape of the design is such that it is difficult to build and therefore expensive'. Secondly, generality, i.e. the application of the symbol's meaning to a multiplicity of objects. And thirdly, vagueness, i.e. a lack of clearcut boundaries of the set of objects to which the symbol is applied. An example is 'the building is tall' in which 'tall' can mean different height to different people or in different places, e.g. a 10 storey building is regarded tall in Britain whereas buildings with less than 40 stories may not be described as tall in Hong Kong.

The essence and power of human reasoning is in its capability to grasp and use inexact' concepts directly. Zadeh (1965) argues that attempts to model or emulate human reasoning by formal systems of increasing precision will lead to decreasing validity and relevance because most human reasoning is essentially shallow in nature. Brandon I (1987) describes that in professional development there is a shift from 'text book' knowledge and general theories towards knowledge gamed from experience, the former being deep, narrow and domain-independent while the latter is shallow, wide and domain-dependent.

To distinguish domain independence and domain dependence, it is best illustrated by the difference between the Bayesian and Baconian approach in statistical inference. For example, the description in a tender document for an industrial building for a supermarket provides a high Pascalian probability for its simplicity and short project duration (because of the available statistics about this type of project), but it provides only a medium to low Baconian probability in this sense since the weight of evidence is rather light, as the site may be located in a traffic deadlock, e.g. near the Dartford tunnel on the M25, may have been a rubbish tip, and so on. It is this latter information that is usually possessed by a professional and he often needs only rules of thumb to make his judgments with regard to the cost and time required, on top of the Pascalian evaluation.

If we accept the contention that the situations which are assumed in the Bayesian inference only occur in the ideal world, then an optimal solution can hardly be found for any problem in the real world. Therefore, an approach to problem solving is to get a 'good' solution instead of an optimal one.

However, since the fuzzy set for each linguistic value defines the conceptual meaning of that value, it is necessary to explore whether people of the same domain, at least, agree with each other the underlying meanings of the linguistic variables on which fuzzy sets are built. It may be desirable to use empirical data to derive the fuzzy set. There are a number of methods available for empirically defining a fuzzy set. Saaty (1974) proposed an eigenvalue approach where elements are rated as to their fuzziness. Kochen and Badre (1974) used semantic differentials. Rodder (1975) proposed the use of a rank- ordering test to define a fuzzy set. In order to obtain consensus on the compatibility function among a small group of experts, Narasimhan (1980) proposed the use of the Delphi method in conjunction with a questionnaire approach. In the Narasimhan (1980) study, the fuzzy set for each linguistic value was empirically determined. However, in some situations, it may be appropriate to empirically define only the most important linguistic values and use the basic concepts of fuzzy set theory to define the other linguistic rating values. The linguistic values may also be predefined for the users who are trained as to their meaning. Clements (1977) used this method and obtained satisfactory results. Zadeh (1965) proposed a series of mathematical derivations to build up various hedged fuzzy sets. However, Leung (1981) found in his empirical studies of the definitions of the hedges on such linguistic variables as temperature and height that Zadeh's mathematical derivations were only special rather than general approximations of the hedges. Leung (1981) further concluded that current theoretical constructs were very far from grasping the psycholinguistic properties of the valuation of linguistic hedges.

Therefore, it is desirable to find out on one hand what the construction professional think of the meanings of various linguistic variables they use to express uncertainty; and on the other hand, whether there is any consensus among the professionals as to these meanings. It is also meaningful to test whether the professional's definitions of linguistic variables using fuzzy sets methodology comply with the basic characteristics of a fuzzy set, i.e. normality and convexity.

ESTIMATING USING RISK ANALYSIS

ERA is primarily a technique of risk identification and analysis utilizing the expected monetary value theory. It is used to replace the 'contingency' section of a project cost estimate by identifying and costing risk events associated with a project. Risks are identified first by the Delphi method within the project team. They are then categorized into either (i) Fixed or (ii) Variable. For each risk event, an average risk allowance and a maximum risk allowance are calculated. The relationship between risk category and risk allowance is shown in Table 1.

Fixed risk events are those which either happen or not happen. If it happens, it will incur the maximum cost; if it does not happen, no cost will be incurred. An example is the need for an additional access road. At early stage of a project, the client might not have considered if an additional access road is required, rendering this a Fixed risk item.. The maximum risk allowance is the cost of constructing this access. The average risk allowance is the probability of the client requiring it times the maximum risk allowance, i.e. the expected cost.

	Average Risk Allowance	**Maximum Risk Allowance**
Fixed Risk	Probability x Maximum Cost	Maximum Cost
Variable Risk	Estimated Separately	Estimated Separately
Assumption	50% chance of being exceeded	90% chance for variable risk 100% for fixed risk

Table 1 Relationship between risk allowance and risk category

Variable risk events are those which will occur in varying degree. The cost incurred will therefore be varying. An example is the depth of pile required to be driven. The maximum risk allowance is estimated by the project team members using their own methods with an assumption that there is only 10% chance that the actual cost incurred will exceed this allowance. The average risk allowance is estimated with an assumption of a 50% chance of the allowance being exceeded. There can be mathematical relationship between the average and maximum risk allowance but it is also legitimate for these 2 allowances to be estimated separately.

Having identified all risk events and calculated their average and maximum risk allowances, the summation of all events' average risk allowance will become the 'contingency' of the project concerned. Because of swings and roundabout effect, it is expected that the contingency will be enough to cover all the risk events identified.

Advantages of ERA

ERA is usually done several times during the pre-tender period. As the project development progresses, those events which were identified to be uncertain will get clarified and be either deleted from the list of risk events or included in the base estimate (a certainty), e.g. the secondary access road. The beauty of ERA lie in its ability to retain the traditional method of presenting a project cost estimate in the form of base estimate plus "contingency". It imposes a discipline from the outset to systematically identify, cost and consider the likely significance of any risks associated with a project. It also aids financial control in having risk and uncertainty costs identified before action is taken to determine precise requirements. It further provides useful data for use in investment appraisal. In short, it is a mechanism for , accountability for public money. Rigorously done, it will reduce the usually, conservative and excessive percentage add-on contingency and lead to better allocation of resources.

Improvements to ERA

In a recent study, Wong (1997) found that estimators who were using ERA expressed the need to improve the technique in several aspects. First, there is a need to provide a database of past projects for reference as it is not normal for all estimators to have actual experience of uncertain events, their probability of occurrence and costs. Second, there is a need to justify and match linguistic expressions with probabilistic expressions. In her study, Wong (1997) also found that estimates made by ERA method exhibited less variability than those made by traditional methods. An average of 69% more funds were reserved to cater for uncertainties in ERA estimates whereas an average of nearly 200% more funds were reserved in non-ERA estimates.

CONCLUSIONS

The recognition of incorporating risk analysis in various stages of a project has gained popularity in recent years, especially for large scale, high value, complex, and intensive projects. The Airport Core Projects (ACP) in Hong Kong demonstrate this trend and need. Traditional risk analysis models have been concentrating on the probabilistic approach such as the monte carlo simulation in which the Bayesian theories take precedence. However, the non-mechanistic environment found in the construction industry does not seem to warrant the use of this approach. The use of heuristics to evaluate risk in a humanistic system is unavoidable. The use of fuzzy sets theory to express uncertainties provides a means for solving the problem in a more systematic way; both for soliciting perception of linguistic variables and for building expert systems. An empirical study of the use of estimating using risk analysis (ERA) revealed that further refinement of fuzzy representation of linguistic expressions is required. The ERA method of risk indentification and analysis has shown initial success with government projects. Further studies are required explore the effects of project size (complexity) and type on uncertainty estimates.

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