MODELLING RISK FOR CONSTRUCTION COST ESTIMATING AND FORECASTING: A REVIEW

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Construction cost estimating is considered one of the most essential tasks in the budget development of any project life cycle. However, it is carried out under conditions of uncertainty. Traditional cost estimating methods are unsatisfactory aids to decision making due to lack of their accuracy especially in feasibility or appraisal stages. Risk management is a form of decision-making within the project management process. Previous research indicated that the construction industry in particular has been slow to realize the potential benefits of risk management. With the introduction of microcomputers, the use of project management techniques has become economical, even for small construction projects. However, dealing with qualitative and judgement-based types of problems has been the subject of a lot of research and attempts that led to the Artificial Intelligence (AI) based models and applications. This research work aims at reviewing different approaches for modelling risk and uncertainty in construction cost estimating and forecasting. It starts with an overview of risk management concepts and fundamentals. Following that, it highlights the different analysis and modelling techniques within the risk management field. Finally, a number of previous research work and case-studies for modelling risk in construction cost estimating and forecasting are presented and reviewed.

Keywords: Artificial Intelligence, cost estimating, fuzzy, and risk management.

INTRODUCTION

> "Risk! construction projects have an abundance of it, contractors cope with it and owners pay for it" (Flanagan and Norman 1993: 1).

All projects or business ventures involve risks of various kinds and types. According to Flanagan and Norman (1993), the construction industry is subject to more risks than other industries. In construction projects, risks and uncertainties are of several types. Some of these are: political, financial, economical, environmental and technical. Many of these uncertainties will involve a possible range of financial outcomes that could be better or worse than predicted. The construction industry in particular has been slow to realize the potential benefits of risk management (Flanagan and Norman 1993). Ward, Chapman and Curtis (1991) outline the reasons why risk management, particularly risk analysis, has not been used more effectively in construction. They identified 'cultural issues' such as lack of knowledge, negative attitudes and mistrust of risk analyses as being the main reasons preventing its extensive use. Uher and Toakley (1999) investigated the application of risk management in the conceptual phase of

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Australian projects. They found that while most respondents to the survey that they conducted were familiar with risk management, its application in the conceptual phase was relatively low. They argued that widespread adoption of risk management is impeded by low knowledge and skill base, resulting from a lack of commitment to training and professional development in that area.

The purpose of this research is to investigate the different approaches for modelling risk and uncertainty in construction cost estimating and forecasting. It is divided into three main parts. Part one provides an introduction and background to the area. The second part explores the different analysis and modelling techniques within the risk management field and their application in construction. Finally, the third part reviews a number of previous research projects and case-studies for modelling risk in construction cost estimating and forecasting.

BACKGROUND

Estimating construction cost is one of the essential tasks in the budget development phase of any project life cycle. However, it is carried out under conditions of uncertainty. The preparation and accuracy of any type of cost estimate will depend heavily on the amount of information available and tools used during different project phases. Traditional methods and operations of cost estimating proved to be unsatisfactory aids in decision making due to their lack of accuracy especially in the feasibility or appraisal stage (Alkass and Jard 2000). During that phase, most projects are budgeted using a "cost per gross floor area" basis regardless of the project's associated risks and their impact on cost and time parameters.

Cost estimating techniques/methods can be categorized in various ways ranging from order of magnitude to usage of artificial intelligent (AI). In most of these methods or techniques, the estimator uses references, manuals or databases for cost-rates. These are normally derived from previous projects or tenders and need to be adjusted for time of use. Previous research on the causes of budget-related problems in US federal construction projects found that 35% of the projects in their sample encountered budget related problems (Committee on Budget Estimating Techniques 1990). Al-Zarooni and Abdou (2000) conducted a survey to investigate variations in UAE public projects' estimates. Statistics showed that variations between the actual and contract cost were at an acceptable level, while there were high variations (positive or negative) between feasibility and contract cost, ranging between -28.5% and +36%, with no clear pattern for those variations. They stated that these variations could be explained knowing that feasibility estimates in the government agencies are usually budgeted using a *Single Unit Estimating (cost per square foot)* basis, regardless of the nature of projects and their associated risks or the construction complexity of each building type. The same authors' research conducted a survey to investigate the use of risk management in the conceptual stage of UAE Public projects. They found that the application of risk management techniques was almost completely neglected in the public projects, especially during the conceptual stage. They argued that applying risk assessment techniques in pre-design stages will lead to better cost estimating and hence better decision-making.

Cost and Price

Cost and price are basic terms when we talk about estimating. According to Ferry, Brandon and Ferry (1999), the meaning of such term depends on where you are looking at it from. They explained that the seller's price is the client's cost. So in a construction project, the contractor's price is the client's cost and the sub-contractor's price is the contractor's cost. Furthermore, Newton (1992) states that " a 'cost ' relates directly to the goods and services consumed in the production of a commodity, a 'price' reflects the amount we are prepared to pay in the exchange for that commodity" (Newton 1992: 432). He concluded that when we speak of cost in estimating we most often actually mean price. So the term 'cost estimate', in this paper, is refers to the total anticipated expenditure required by the client, to complete a certain building project.

Definitions and Framework of Risk Management

"The word risk is quite modern; it entered the English language in the mid 17th century, coming from the French word *risqué.* In the second quarter of the 18th century the anglicised spelling began to appear in insurance transactions" (Flanagan and Norman 1993: 2).

When reviewing the literature, some disagreement regarding the distinction between risk and uncertainty can be found. On one hand, there are those who consider risk and uncertainty as distinct concepts. This distinction can be found in the way that a risk can be measured in term of its impacts and their probabilities, while uncertainty is hard to measure objectively, especially in term of probability issues. On the other hand, others regard risk and uncertainty as so strongly related to each other as to be synonymous. Newton (1992) states that the counter argument to the dissimilarity of risk and uncertainty recognizes that they are inevitably defined in terms of one another, and to distinguish them might even be unhelpful.

Risk management (RM) is a well known field in many industries. For example, in the insurance industry, risk management is a basic practice. According to Raftery (1994), risk analysis and risk management had their origins in the insurance industry in the USA in the 1940s. However, when reviewing the best known insurance text books, there is a general lack of agreement concerning the definition of risk (Vaughan 1986). Most terms are explained in one of the following ways: (a) risk is the chance/ possibility of loss; (b) risk is the probability of any outcome different from the one expected; (c) risk is the dispersion of actual from expected results; (d) risk is uncertainty.

In the context of project management, different definitions could be found for 'risk'. Raftery (1994) states that "risk and uncertainty characterize situations where the actual outcome for a particular event or activity is likely to deviate from the estimate or forecast value" (Raftery 1994: 5). The Project Management Institute’s “Body of Knowledge” defines risk as: "… an uncertain event or condition that, if it occurs, has a positive or negative effect on a project objective" (Project Management Institute 2000: 127).

Various frameworks for the RM process are presented in reputable risk management literature. According to Jackson and Flanagan (2002), selecting an appropriate framework is the first step to planning for implementation of risk management processes. They give an example of recent theoretical frameworks such as: the Construction Industry Research and Information Association (Godfrey 1996), Association for Project Management (Simon, Hillson and Newland 1997), Institute of Civil Engineers and the Faculty and Institute of Actuaries (1998) and the British Standards Institution (2000). They state that the number of stages, the tasks undertaken in each stage and the terminology used are varied and therefore confusing. For example, risk identification and risk analysis are sometimes two individual stages, sometimes they are combined and called risk assessment or risk review. Risk response is sometimes called risk planning, evaluation, treatment, control or mitigation (Jackson and Flanagan 2002). Another recent example is given in the PM Body of Knowledge (Project Management Institute (2000). This defines risk management as the systematic process of identifying, analysing, and responding to project risk. The book presents a six stage framework for risk management as: risk management planning; risk identification; qualitative risk analysis; quantitative risk analysis; risk response planning; risk monitoring and control.

RISK MANAGEMNT ANALYSIS AND MODELLING TECHNIQUES

When reviewing the literature on risk management in construction, different techniques for analysis and modelling risk could be found (Flanagan and Norman 1993, Raftery 1994, Byrne 1996, Grey 1998, Smith 1999, Project Management Institute 2000). These techniques include: The Risk Premium; Risk-Adjusted Discount Rate; Subjective Probability; Decision Analysis; Sensitivity Analysis; Expected Monetary Value (EMV); Delphi Method; Expected Net Present Value (ENPV); Monte Carlo Simulation; Portfolio Theory; and Stochastic Dominance. The use of Computer-Based tools such as Casper, @ Risk or CrystalBall was also reported.

The following paragraphs give a brief description for these techniques.

The Risk Premium: in this technique, the estimator adds margins to his estimate to cover unforeseen problems or uncertainties. It is more commonly known as the contingency fund in the UK and conservative estimate in North America (Raftery 1994). The amount of premium varies according to the estimator own judgement of the project nature and its associated risks. According to Flanagan and Norman (1993), this kind of decision making techniques is used as a risk respond technique.

The Risk-Adjusted Discount Rate (RADR): This technique is easy to understand and to calculate. It is an intuitive method of dealing with risk. It uses some adjustment to reduce the calculated present value of future income (Raftery 1994). According to Flanagan and Norman (1993), most companies using risk-adjusted discount rates employ a risk classification scheme to minimize bias in evaluation of different type of projects. It is also argued that this techniques is not suitable specifically for construction industry and it is commonly used in banking and business (Raftery 1994).

Subjective Probability: this technique is based on using knowledge and experience gained from similar projects undertaken in the past. According to Flanagan and Norman (1993), this method is deemed to be useful when decision making is characterized by risks rather than uncertainty where there is a history of outcomes that can be aggregated to produce objective. However, it is argued that any project or business environment chances continuously and the risks of yesterday might not have the same probability or impact outcomes today. They added that this technique can be more effective and objective by integrating it with a *Delphi* approach to group or team considerations of probabilities.

Decision Analysis: "is a technique for making decisions in an uncertain environment that formally treats both risk exposure and risk attitude. It provides a methodology to allow a decision-maker to include alternative outcomes, risk attitude and subjective impressions" (Flanagan and Norman 1993: 75). Decision analysis has a set of techniques to guide decision taking dealing with risk and uncertainty. Its methods include: algorithms; means-end analysis; decision matrix and decision tree. An algorithm contains a sequence of instructions for problem solving. In the means-end analysis/chain method, a chain of objectives is clarified to identify a series of decision points. The decision matrix method uses a form of matrix to represent the options that a decision maker can take, the factors that are relevant and the possible outcomes. In the decision tree, the sequence of possible choices and their possible outcomes is shown graphically in the form of tree. Decision tree are extensively used in managerial decision-making (Flanagan and Norman 1993). According to Akintoye and Macleod (1997), the decision tree method is useful in deciding methods of construction, choosing alternative projects, and in the contractual problems as well. A stochastic decision tree analysis technique combines the decision tree analysis technique with Monte Carlo simulation.

Sensitivity Analysis: it is a quantitative technique that allows the effect of economic changes in a project to be explored. It is carried out by identifying the project variables and giving them a range with which it is expected to vary (Smith 1999). It is used to explore the impact of a single risky variable on the project outcomes. This technique requires that the project be modelled usually by computer. Although this technique is very helpful in identifying the variables to which the project is sensitive, it is argued that it has a limitation modelling the real situations as it assumes, when examining one factor, that the others remain the same, which is not likely to be the case in reality.

Monte Carlo Simulation: it is a form of stochastic simulation. It was developed a number of years ago and has become one of the most well known and widely-used probabilistic risk analysis techniques (Smith 1999). In this approach, the values of variables are represented by probability distributions and the analysis hinges upon the ability to select random values from these distributions. For example, a cost estimate for a project may be built-up from the estimates for its individual elements (substructure, superstructure etc). Applying Monte Carlo methods to this task would involve selecting a single value from the distribution for each element and thus computing one possible value of total cost. This process can then be repeated many times to produce a distribution of total cost. Computer software is required to tackle Monte Carlo simulation on “real world” problems, because of the large number of repetitive calculations involved in the process.

Portfolio Theory: This technique is originally practiced in business. The aim of portfolio analysis is to maintain the expected return and to minimize exposure to risks of the portfolio. A company portfolio is the company's various types of investments such as stocks, projects and properties. According to Flanagan and Norman (1993), in the construction industry and property market, building firms can create a project portfolio, in which each building/project type has its own expected return and risks. They give an example of housing and high tech. commercial offices. Each of them has its own risks and different return. The portfolio management concept has received a great deal of attention recently specially in the United States. The market for IT tools that support the portfolio management processes is growing very fast. In 2002, it was about $85 million; it could reach $540 million by 2005 (Datz 2003).

Stochastic Dominance: this method in not a technique of risk analysis. It is a method of assessing results. Its main objective is to compare the probabilistic result of different projects e.g. those produced by Monte Carlo simulations. According to Raftery (1994), this method is largely informal and the results chosen may depend on personal risk attitudes of those reviewing the graphs.

Computer-Based tools: the computer based tools main objective is to facilitate the analysis of risk and their impact. Some of these tools operate within a spreadsheet, such as @Risk or Crystal ball. According to Grey (1998), such tools that work with a spreadsheet like Excel for example, have the advantage that a large part of their user interface is both easy to use and familiar to the large number of people. The Caspar tool, developed in the Center for Research in the Management of projects, at the University of Manchester Institute of Science and Technology by (UMIST), designed to model the interaction of time, cost and revenue throughout the entire project life cycle (Project Management Group 1989). It assists with the identification and analysis of the financial and construction risk associated with the project. Another famous and comprehensive project risk modelling tool is Monte Carlo by Primavera. In addition to cost and schedule modelling, it can represent integrated cost-schedule models, taking account of project resources and other constraints (Grey 1998).

A number of projects have investigated the use of risk management in the construction industry. Mok, Tummala and Leung (1997) conducted a survey to investigate the application of risk management process (RMP) in preparing building services cost estimates in Hong Kong. The results show that about 80% of the respondents used subjective/intuitive assessment in measuring risks. If the respondents used RMP, the most common technique was 'estimating using risk analysis (ERA)'. ERA is a technique introduced by Hong Kong government to be used in all public work projects (see below). The authors conclude that even though the results of the survey indicate that the risk management process has not been widely adopted in the Hong Kong construction industry, the industry generally accepted that the use and application of RMP will become more and more important in the future, and believed that RMP will improve the quality of cost estimating.

Akintoye and Macleod (1997) conducted a questionnaire survey to investigate the use of risk management in the UK construction industry. The results show that the use of risk analysis techniques by the responding firms is generally low in construction projects, with the exception of intuition/judgement/experience. Most of the respondents were familiar with sensitivity analysis techniques; this was followed by decision tree, Monte Carlo simulation and subjective probability. The respondents were asked for the reasons why some of risk analysis techniques are not used in their firms. Lack of familiarity featured prominently among the reasons given and was followed by claims that the amount of calculations when using the techniques was unwarranted in order to meet the project's objectives of time, cost and quality (Akintoye and Macleod 1997). The authors conclude that risk analysis and management in construction depend mainly on intuition, judgement and experience. Furthermore, formal risk analysis and techniques are rarely used due to a lack of knowledge and to doubts on the suitability of these techniques for construction industry activities. The authors called for attention to be given by construction researchers to this problem in order that the practical value of such techniques can be increased.

Al-Zarooni and Abdou (2000) conducted a survey to investigate the use of risk management in the conceptual stage of UAE Public projects. They found that the application of risk management techniques is almost neglected in the public project especially during the conceptual stage. Of the available risk analysis techniques, probability, decision tree and sensitivity analysis were the most used. While most of the respondents (74%) were familiar with risk management, only 26% of them indicated that they used the techniques in their work. The authors concluded that utilizing information technology (IT) by developing computer systems that integrate risk analysis technique for each building type will help in facilitating and widening the use of risk management as a decision making tool in the construction industry. A similar opinion was expressed by Ho and Pike (1992), who expected that the increasingly widespread use of microcomputers in financial modeling packages will add to the potential, easy of use and efficiency of risk analysis in capital budgeting (Akintoye and Macleod 1997).

MODELLING UNCERTAINTY IN CONSTRUCTION COST ESTIMATING AND FORECASTING: RELATED CASE STUDIES

Models are found on a variety of format and are used for several purposes. "a model must capture and represent the reality being modelled as closely as is practical, it must include the essential features of the reality whilst being reasonably cheap to construct and operate and easy to use" (Fellows and Liu 1997: 62). Most models contain variables that need to be identified and quantified with some kind of correlation for the use in the model. According to Fellows and Liu (1997), the resultant models are either deterministic or stochastic. A deterministic model tends to be simpler and doesn't take probability in account while the stochastic models mimic reality by incorporate the effects of probability.

Fellows and Liu (2000) classify building price/cost models into two categories: client-oriented and constructor-oriented. The authors reported on Fortune and Hinks (1999), that when examining the use of building price models in the UK, there is continuing, widespread use of traditional, deterministic approaches such as square meter, approximate quantities, elemental and judgemental estimating. Furthermore, there is only minimal use of other advanced techniques namely: causal cost models, regression, time series and simulation that may involve statistical approaches. The client-oriented deterministic cost models are commonly used throughout the design stage to specify the expected project cost to the client. Such models are usually derived from databases that have cost records from past projects, adjusted to the time of use, rather than the more appropriate market price models of economic theory and project award practice. On the other hand, in the constructor oriented-models, the initial indicators of costs are obtained from sub-contractors' bids during bidding time.(Fellows and Liu 2000).

The main purpose of modelling risks/uncertainty in construction cost estimating and forecasting is to reflect the effect of associated uncertainty in the cost estimating process to have more realistic estimate. It will present a clearer vision with more information to the decision-making process from both the client’s and the constructor’s side. The following paragraphs describe previous research work and case studies for modelling risk and uncertainty in the cost estimating and forecasting process.

The Hong Kong government introduced a cost estimating methodology, 'Estimating using risk analysis' (ERA) in 1993, to be used in all public work projects in the country (Mak and Picken 2000). It substantiates the traditional contingency allowances by identifying uncertainties and estimating their financial impacts. The main reason for introducing such a methodology arose from the need to overcome the inflated contingency allowances which are sometimes proposed by the project team in an attempt to overcome the need to seek additional funds if there is any cost overrun. Concentrating on the major risks, the starting point of the ERA process is the base estimate of known scope and risk free elements. The underlying philosophy of the approach is to identify the areas of uncertainty and risk on a project and indicate what the risk is and the likelihood of its occurrence. Following that, the uncertainty and risk items are categorized as either fixed or variable. Then the amount of allowance is added to the base estimate, with backup calculations, of the likely expenditure associated with the possible risk or uncertainty. As the project is developed through the various stages, the process of risk analysis and identification seeks to reduce the level of uncertainty. According to Mak, Wong and Picken (1998), the details of ERA can be found in United Kingdom Government publications 'HM Treasury' (1993) and it is similar to a 'Multiple Estimating using Risk Analysis' technique referred to by Raftery (1994).

A comparison of the viability and consistency of contingency estimates between non-ERA and ERA Projects in Hong Kong was the subject of a study by (Mak, Wong and Picken 1998) and (Mak and Picken 2000). A total of 287 non-ERA and 45 ERA projects were studied. According to the authors, the findings showed that the use of ERA approach has improved the overall estimating accuracy in determining contingency amounts. They suggested increasing the number of examined projects and clustering them according to their size and types to explore the effect of type and size on the uncertainty of the estimate. The advantage of the ERA approach, that enables it to be adapted in the Hong Kong construction industry, is that it retains the traditional method of presenting a project cost estimate in the form of a base estimate plus a contingency and it produces a deterministic figure in advising client of the likely cost estimate of the project.

Stochastic modelling that incorporates probability and uncertainty into construction cost estimating and forecasting was investigated by (Birnie and Yates 1991). They suggested the use of decision tree, utility theory and the Monte Carlo simulation techniques in the cost prediction process. The approach was applied to a housing refurbishment contract. The study compared the actual project final cost with the predicted range, the result show the figure was with in the predicted range. Merna and Storch (2000) performed a risk analysis for an agricultural investment project using the CASPAR tool. A sensitivity and probability analysis were conducted on the project base model that led to prediction of the quantitative effect of risk factors associated with the project. The results were used to develop a plan for risk response, especially for the critical factors observed from the results. The authors argued that the tools can be used not only for the appraisal of a construction projects, but applied to any type of investment where cost and revenue can be allocated to a network of activities.

The application of “Fuzzy” approach in modeling uncertainty in construction cost estimating and forecasting has been the subject of several research recent projects. The 'Fuzzy Set theory', first introduced by Zaden 1965, presents an approach to handle inherent uncertainty. According to Baloi and Price (2003), the main concepts associated with the Fuzzy Set theory, as applied to decision systems, are membership functions, linguistic approximation, fuzzy set arithmetic operations, set operations and fuzzy weighted average.

Baloi and Price (2003) sought to develop a fuzzy decision framework for contractors to handle global risk factors affecting construction cost performance. They discussed the core issue of global risk factors modelling, assessment and management. Major global risk factors were identified through extensive literature review and preliminary discussions with contractors. According to the authors, the term 'Global risk' refers to type of risk factors that are not directly present in cost estimates yet may lead to significant financial disasters. They are called so because they transcend the boundaries of the organization and yet they have large impact on it such as economic or political related factors. The authors discussed different techniques for handling uncertainty and they conclude that the global risk factors affecting construction cost performance can be successfully modelled and assessed using Fuzzy Set theory and decision support systems. They added that in order to build the knowledge base part of the proposed fuzzy decision support system, the global risk factors need to be determined and linguistic variables have to be defined with reliable membership functions.

Carr and Tah (2001) presented a construction risk management prototype system that integrated a fuzzy approach for risk assessment and analysis. According to the authors, the main aim of the system is to facilitate practical and effective risk handling whilst allowing those involved in the process to develop a greater understanding of project risk, resulting in improved project and corporate performance. The system has been developed using a conceptual, three-tier client/server architecture (See Figure 1). They separate the user with its interface, from the rules (server) and the data (database). One of the main benefits from using such architecture is separation of data from the other parts. This enables an easier modification to the data, if needed in future. Within the system, the effects of risk were introduced by four characteristics (time, cost, quality and safety) and fuzzy logic has been implemented for the analysis process. Using fuzzy logic and the magnitude levels of risks that affect the tasks and the project, the impact on the four characteristics can be calculated. The authors recommended that work is needed to improve the qualitative risk assessment module and to refine the prototype to be more acceptable to construction practitioners.

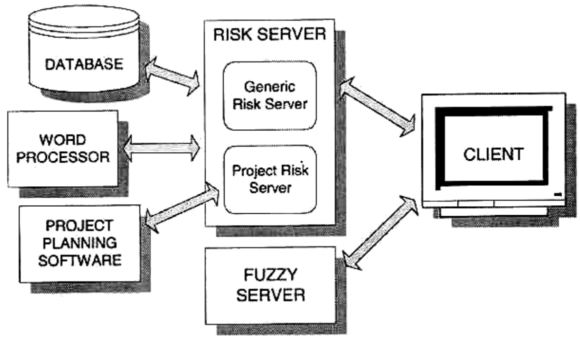

Figure 1: The three-tier client/server architecture for the risk system. Source: (Carr and Tah 2001)

The expectation of the construction industry for ease-of-use in the techniques for risk analysis and management has shaped many recent research projects. Chapman and Ward (2000) suggested an approach to the estimating and evaluation of risk and uncertainty process. It was designed to be easier to use than probability impact grid based approaches and linked qualitative and quantitative approaches. According to the authors the approach is based on the general view of uncertainty which incorporates ambiguity as well as variability and lack of data. One characteristic of the approach is the concern for identifying sources of uncertainty. Other characteristics of the approach include deliberate conservative bias to counteract persistent underestimating of uncertainty. The approach is set in the context of an iterative approach to an overall uncertainty management and involves six steps in its attempt to estimate and evaluate uncertainty and risk. The first step is to identify the parameters to be quantified. It includes setting out the basic parameters of the situation, the composite parameter structure, associated source of uncertainty/risk and a determination, in relation to each parameter, whether or not probabilistic treatment would be useful. The second step will estimate crude but credible ranges for probability of occurrence and impact. This will be conducted for only those factors for which a probabilistic treatment was identified in the previous step. The third step is to recast the estimates of probability and impact ranges. It will involve reflecting more values of probability and possible impact rate (very pessimistic and very optimistic) by applying percentage factors to previously identified values. The following step involves calculating the expected values and ranges for the project parameters from step one using the midpoint values from step three in association with other assumed plausibly pessimistic values. Step five involves presenting the results graphically (optional) and last step is to summarise results. The minimalist approach which presented by the authors uses ranges primarily to obtain an estimate of expected impact in terms of cost or time. It is simple, timely and could be easily adapted by the industry.

Recently, Jackson and Flanagan (2002) suggested a conceptual model to integrate a risk management system into conventional project cost estimating procedures during the appraisal stage of a project. The authors suggest a twelve step procedure to enable cost estimators to integrate risk management into everyday professional practice. The model's main objective is to generate a risk report that will initiate the project budget risk management cycle. They further argue that integrating a risk management system into the estimating process, with additional resulting information about the impact of possible risks on the project budget; will lead to improved client decision making processes. They added that it will also help to satisfy the increasingly demands of today's risk aware clients and will promote cost estimators into a leading strategic position (Jackson and Flanagan 2002).

The previous two approaches represent an effort to respond to the concerns raised by many researchers (Akintoye and Macleod 1997, Mok, Tummala and Leung 1997) on the practical value of current risk assessment techniques to the construction industry.

CONCLUSION

The objective of this research is to investigate the different approaches for modelling risk and uncertainty in construction cost estimating and forecasting. The fundamentals of risk management concepts and the different analysis and modelling techniques within the risk management field are presented. Following that a number of related research work and case-studies for modelling risk in construction cost estimating and forecasting are presented and reviewed.

Understanding of the sources of risk/uncertainty through the identification and classification stages is very important to the success of chosen techniques for the analysis stage. There is no single analysis/modeling technique that is best for construction projects. The best selection will depend on the project parameters and possible historical data available at the time of analysis.

It was observed from the different research work that the application of risk analysis and management in the construction industry was relatively low compared to other industries. To widen their integration into the current estimating and forecasting process, the researchers need to find ways of seamlessly building them into existing methods in common use.

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