First International Conference on Construction in the 21st Century (CITC2002)
"Challenges and Opportunities in Management and Technology"
25-26 April, 2002, Miami, Florida, USA

A RISK MODEL FOR APPRAISAL OF CONSTRUCTION PROJECTS AT TENDER STAGE

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ABSTRACT

This paper describes a project risk model which has been developed to combine the various sources of uncertainty to allow the effective communication of the uncertainty with respect to the objectives for the project. The identification of the sources of uncertainty is the most difficult part of that process, which uses proven techniques of checklists and structured brainstorming. A simple method of modelling those uncertainties, here termed risk factors, is used. Monte Carlo simulation is used to combine those various sources, producing the uncertainty in the project. In order to enable the communication of the resulting risk and opportunity, a classification system was developed which related the uncertainty to the objectives. This classification was shown to adequately reflect the views of managers when changes to a test project were made or projects were compared. The project risk model was tested on projects as their tenders were being produced. This approach to testing in a live situation confirmed the applicability of the model in practice as well as in theory.

KEYWORDS

Construction, Risk, Model, Project Appraisal, Cash Flow

1. INTRODUCTION

The construction industry in many countries is undergoing radical changes whereby many construction companies are entering into new types of contracts which allocate risks to them which have previously been held by others.

The traditional approach to managing the risk from projects has utilised the valuable assets of manager's experience and judgment. Interestingly, the term " risk management" has only been in common use for the last two decades. This is because the term refers to treating the risk management of risk as an explicit task. Traditionally, the management of risk, using experience and judgment, has not been separated from other functions of managers and so not warranted a title.

The application of experience and judgement in the traditional approach has been targeted at the time in a project when most can be done to manage the risks it generates. This time is the tender stage. It is at this time that the company submits a bid for a project based on a set of contract conditions. The reliance on experience which, in some cases, may not be relevant may be seen as the major deficiency in the traditional approach. This approach requires the management to make judgements of the extent to which the company wants the project, the price which is likely to win it, the risk the company is already exposed, and the risk this project would expose the company to if the tender was successful.

In order to overcome the deficiencies in the traditional approach described above, a more formal, scientific approach was needed. The subject of risk management has been developed over the last few decades, bringing together many systems and techniques with the objective of doing just that.

A literature review has revealed that there are many definitions of risk management, just as there are of risk, see for example, A-Bahar and Crandall (1991), Bannister and Bawcutt (1981) and Flanagan and Norman (1993). The review has also shown that there is no consistency in the definition of risk, this is compounded in the definitions of risk management.

There is also disagreement on the matter of what should be the focus of risk management within construction. Many of the definitions define it in terms of construction projects ignoring the fact that the risks are ultimately to the company undertaking them. When risk is viewed purely from a business perspective, as in Bannister and Bawcutt, 1981, the field of view is widened and risk management is defined in terms of a company and its operations. Indeed, Perry and Hayes (1985), identify the benefit of understanding the cumulative effect of project risks but concede that this is not undertaken.

Many authors, rather than providing a definition of risk management, describe the process and, in doing so, definitions can be inferred. Risk management is described by many as a three stage process (Perry and Hayes, 1985, Clark, Pledger and Needler (1990), Bannister and Bawcutt (1981), and Toakley and Lind (1991) entailing identification, analysis, and response.

In this work a model is developed at the project level, which considers the sources of uncertainty in the project and which can be extended for use at the company level. This is done by combining the uncertain impacts of the projects it is undertaking, those it is pursuing, and those which it expects will be available in the future.

The model has been tested and validated using data collected from projects in their tendering stage. The results of the tests are presented and conclusions are drawn.

The following sections of the paper describe of the various aspects of the suggested model.

2. SUGGESTED PROJECT RISK MODEL

2.1 Basic Inputs to the Model

The model is based on the uncertainties in the project cash flow. To define the cash flow, in its most basic form, requires the start date, duration, cost, and tender value for the project. At tender stage, the value is unknown and so an estimate of cost is used to which the typical overhead and profit mark-up are added. These parameters define the base cash flow, assuming the worth of the project is uniformly distributed throughout the project.

The uncertainties which will be identified will be quantified in terms of their impact on the base cash flow. The base cash flow used should, therefore, be as representative as possible of the expected cash flow. If a detailed cash flow has been produced during the production of the estimate, the values in each month should be used as input to the model.

In practise, it is very rare that a detailed cash flow exists when the risk model is to be produced. In this case, the accuracy of the cash flows can be increased by defining phases within the project. Each phase will last for a proportion of the duration and account for a proportion of the cost and value. The phases, for example, can be relating to design, construction, and commissioning.

2.2 Sources of Uncertainty in the Base Cash Flow

Although project risk management usually looks to the final outcome of the project as a measure of performance, the company will be concerned with the performance of the project throughout its duration. A company will want to know the cash flow of the project in addition to its final outcome to assess its financing needs with relation to the requirements of other projects. So, although the project team will want to know the combined effect of uncertainties on the final profit of the project, the project risk model considers the uncertainties with reference to their timing in addition to their impact.

The identified uncertainties which can affect the cash flow are here termed risk factors. A risk factor is defined by its chance of occurrence and then its effect on the cash flow if it does occur. By defining a risk factor in terms of its effect on the cash flow, a single risk factor can affect both the cost and duration of the project so removing the confusion of a risk which has several effects on the project.

2.3 Identification Techniques

Identification is arguably the most important step in risk management, as only identified risks can be analysed and subsequently managed. The business unit requires confidence that the single source of uncertainty the project risk model produces is an accurate assessment of the uncertainty in the project. This confidence can only be gained by applying a structured approach to the identification of risk factors. For this reason, the use of the structured brainstorming and checklists techniques, see Harrison (1995) and Al-Bahar and Crandall (1987), are encouraged.

Brainstorming sessions promote the discussion of the issues within the project in an open forum. The objective of such a session is to produce a list of the sources of uncertainty in the project. Although the project risk model will only contain those which can have an impact on the cash flow, other uncertainties should also be considered. These uncertainties usually relate to the contract and the liability of the company in the event that the project fails.

Another measure to ensure all aspects of the project are investigated is to have a list of areas which have to be addressed. Typical aspects for discussion are site, client, design, subcontractors, construction methods/materials and suppliers. These six topics form a starting point for a checklist in that they represent areas which have to be addressed. The level of detail is such that they do not allow experience to be represented and so should only act as a starting point.

The next stage in the development of a checklist would be to discuss the issues which are important in each area.

2.4 Risk Quantification

A risk factor is fully defined by the probability that it occurs and the effects on the project’s cash flow if it does.

The probability of occurrence can very rarely be defined using historical data; even risk factors which exist on the majority of projects will be affected by the nature of the project and local conditions. Subjective assessments are therefore used to determine, between the members of the project team, the probability of occurrence. This is a task which benefits from representatives of the whole project team being present as it limits the effects of bias. Additionally, once several risk factors have been assessed, the probabilities of occurrence can be compared, testing the logic used.

There are many ways in which the uncertain effects can be defined but again, since accurate historical data rarely exists, statistical based distributions cannot be readily defined. To overcome this problem, a limited number of easily defined distribution shapes are used. These include event, rectangular, triangular, trapezoidal and dual range distributions.

2.5 Risk Analysis

The two main objectives of the project risk model relate to the evaluation of the uncertainty to either produce a single source of uncertainty to represent the project in the company risk model or to allow the project to be classified. The objective of the analysis is then to combine the risk factors to produce an uncertain cash flow for the project. Monte Carlo Simulation is an ideal technique for this task as it was specifically developed to offer a means of estimating the combined effect of many distributions. It is a sampling technique used to evaluate a function which contains uncertain variables. The cash flow of the project is the function to be evaluated within this model.

2.6 Evaluation of the Base Cash Flow

The first stage of each run of the simulation is to evaluate the base cash flow which the risk factor effects will be added to or subtracted from. If, however, all the uncertainty was defined using risk factors, the base cash flow would be identical on each run and so would be evaluated once for the entire simulation.

If the start date of the project is uncertain, a value is selected from the distribution defined.

Although the actual start date may have little implication on the project, it is likely to be important to the business unit. The start date fixes the base cash flow and the risk factors for which dates were specified in time, the remainder usually being defined in terms of durations from the start date.

If general uncertainty has been defined, the cost, value, and duration of the base cash flow must be selected from their distributions. In the case that all the uncertainty in these parameters has been defined using the risk factors. The cost, value, and duration and the phase durations are used to complete the definition of the base cash flow. The total values are used to scale the relative costs and durations for each project phase.

2.7 Risk Factor Effects

Risk factor occurrence
The first stage of this process is to determine which risk factors occur for the run of the simulation being evaluated. For each risk factor, the probability that the factor occurs has to be defined as explained in "Risk Quantification" section. If the random number generated is less that the probability of occurrence the risk factor occurs

The remainder of the discussion of risk factor effects applies only to those which occur on the run of the simulator being evaluated.

Risk factor start and end dates
The project risk model is not purely seeking to determine the uncertainty in the final outcome of the project and so the timing of the risk factor effects is important. The start and end dates of the effects for each risk factor are defined, either as finite dates or distributions. For those defined as a distribution, the start date is selected at random.

The end of the risk factor effects is defined as a date, rather than defining a duration for the effect. A similar process is performed to select the end date of the effect for those risk factors where a distribution is defined.

Risk factor duration effects
Unlike the cost and value effects, the duration effects affect the whole cash flow, rather than over the period of the risk factor. If a duration effect has been defined, the effect on the project for the run under consideration is selected from the distribution and added to the project duration. Having repeated this for all the risk factors which occur, the base cash flow is amended to take into account the new duration of the project.

Risk factor cost and value effects
If a duration effect has been selected, and if a relationship between cost, value, and duration is required, the same random number is used to select the financial effects. If no duration effect has been selected, or a relationship is not required, random numbers are generated with which the effects are selected. It is assumed there is a relationship between cost and value, and so the same random number is used for cost and value, regardless of whether a relationship with time is assumed.

The effect selected is the total for that risk factor and is distributed uniformly between the start and end dates of the risk factor. Repeating this process for all the risk factors which occur on the run produces the final cash flow for the project for that run.

2.8 Interpreting the Output of the Model

Uncertain cash flow
The main objective of the project risk model is to combine the various sources of uncertainty in the project's cash flow into a single source. The collection of possible cash flows for the project will act as this input to the company risk model.

Distributions of Final Outcome
A further objective of the project risk model, when applied to the project being tendered for, is to give an assessment of the uncertainty in the project to act as a basis for decisions regarding the tender price. In addition, if analysis is performed while the tender is being produced, it may show that the project contains an excessive amount of uncertainty and allow the approach taken for the project to be changed to control that uncertainty. For example, different materials may be used, or the order in which elements are constructed may be changed. Such actions may, in addition to reducing uncertainty, increase cost. The need to have a detailed analysis of the uncertainty is therefore essential if such decisions and the submitted tender price are to be made with confidence.

In order that such action can be taken, a means of presenting the uncertainty is required. This must be in such a form that it can be readily communicated and allow comparison with the results of an analysis using the different approach.

The distributions of final outcome for cost, value, profit, and duration can be produced while the analysis is being performed. Although they only illustrate the uncertainty in the final outcome of the project, it is on this information that the project will be assessed.

From the distributions produced, statistical measures can be evaluated which quantify the uncertainty. Such measures are required in order that comparisons can be made and the results communicated. Of the many parameters which can be evaluated from a frequency distribution, the measures which are required are those which reflect the likely outcome, the range of possible values, and the distribution of values between the two. The parameters in Table 1 reflect the desired measures, showing their values for an example project.

Table 1: Statistical Results For The Example Project

Statistic	Cost	Value	Profit	Duration
Mean	3 049 388	3 225 000	175 612	11.000
Standard Deviation	27 757	0	27 757	0.000
Best Case	2 968 803	3 225 000	256 197	11.000
Worse Case	3 166 275	3 225 000	58 725	11.000
Theoretical Best Case	2 920 000	3 225 000	305 000	11.000
Theoretical Worst Case	3 248 000	3 225 000	-23 000	11.000

The best and worst case produced within the simulation and theoretical extremes are presented to illustrate the difference between the two. The theoretical extremes are the outcomes if all the risks occur with their maximum impact with none of the opportunities and if all the opportunities occur with their maximum impact with none of the risks. These define the limits beyond which the outcomes cannot fall. However, these extremes, due to the compounding of sometimes unlikely uncertainties are extremely unlikely to occur. The extremes produced by the simulation offer are more likely range of outcomes for the project.

In any project it is accepted that there is a significant amount of risk and if all those risks occur the project is likely to lose to the company money. When deciding the tender price, it is the likelihood of risks occurring which are important and so more importance is given to the likely range given by the simulation rather than the theoretical maximum.

2.9 Risk and Opportunity Classification

Although the statistical measures offer parameters against which other projects and variations on the one under consideration can be compared and a means of communicating the results, they only reflect the uncertainty in the project and require all the results to be presented to be meaningful. In order to relate the uncertainty to the desired outcome of the project, and offer a single result for the purpose of communication and comparison, the resultant uncertainty is classified for risk and opportunity.

The purpose of the classification system is to relate the uncertainty to the objectives of the project; in order to allow the communication of the result however, it must do so in a manner which can be readily understood to people not directly connected with the project. In order that this is achieved, the classification system must be calibrated using projects with which the teams are familiar, enabling the classification to reflect their views of the project.

Although ideally a single classification would be produced for the uncertainty against the objective for profit, say producing a result on a scale of 0 to 10, it is not possible to reflect the balance between the risks and the opportunities and the magnitude of them using a single number. For this reason, a classification is produced for the risk and one for the opportunity, allowing both the magnitude of each and the balance between the two to be communicated.

Objectives against which the uncertainty is classified
Although at tender stage the project may not have clear targets for profit, an assessment of risk and opportunity can be made against the standard rules of the business unit, which might include an addition to cost relating to overheads and profit. For the purpose of classification, a risk is an outcome of the project which would cause the project to make less profit than its target, while an opportunity would result in a profit greater than its target. The cut-off point between risk and opportunity is here called the threshold level, denoting the threshold between risk and opportunity.

The threshold level can be set at various values, three of which are:
- the cut-off between absolute profit and loss,
- the level at which the project only makes its contribution to overheads,
- the level at which the project returns its target margin, representing both overhead and pure profit.

If further objectives, in addition to that for profit, where applied to projects, the risk and opportunity to these objectives would also be classified.

Classification functions
Since the objective for profit is based on the final profit, it is the distribution of final outcome which is considered when classifying the risk and opportunity. If objectives for the profit at stages in the project had been defined, the distributions at those stages would also be used. For example, an objective might be that the project should not operate a negative cash flow, for which the distribution of cash flow at all stages of the project would be assessed.

When viewing the distribution of final profit with reference to the target, or threshold level, several aspects are considered. These are the most likely outcome, the range of profit, and the probability of being above or below the threshold. In order to produce the single classifications for risk and opportunity, functions are applied to each aspect and the results of these are then combined to produce the classification.

3. TESTS AND RESULTS

The model described above was tested on fifteen projects of various type, value, and complexity. The projects were both civil engineering (roads, water, tunnelling) and building based reflecting both traditional and design-build. The purpose of the tests was to investigate the extent to which the model attains its objectives of modelling the uncertainties in individual projects. There are two aspects to this process. As stated earlier, only identified risks can be actively managed, and so the identification process requires investigation, as does the methodology for quantifying the effects of the identified risk factors. This first aspect is concerned with the input to the model. The second aspect concentrates on the output of the model and how it is produced and interpreted. In addition to this, once the uncertainty has been analysed, the ability of the risk and opportunity classifications described in the previous sections to represent that uncertainty needs to be investigated.

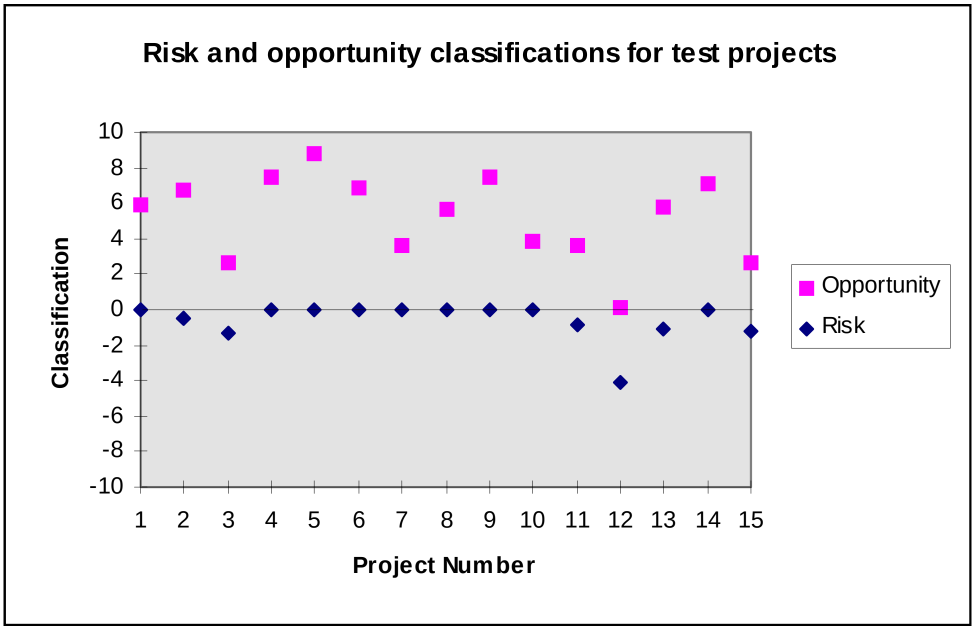

Figure 1: Risk And Opportunity Classifications For Test Projects

The projects were tested as they were being tendered for with input from the project teams. The uncertainties in each project were identified using the techniques of checklists and brainstorming during a facilitated workshop to which all members of the particular project team were invited. This process has resulted in the identification of risk factors for each project. The number of risk factors identified ranges between from 5 to 23, with fairly even distribution between these two extremes.

The second stage of the process involved the quantification of these risk factors (i.e. their probabilities of occurrence, timings, and selecting the shape of distribution which best model their effects).

Figure 1 shows typical output results produced by the model. The Figure shows the risk and opportunity classifications for the test projects. For clarity, the opportunity classification is plotted above the line, while the risk classification, to reflect its negative impact, is plotted as a negative value below the line.

The results shown in Table 2 demonstrate the extent to which the classification system can assist in the process of project appraisal at tender stage . These results are related to test project 1. Since the results produced relate to an analysis undertaken during the period in which the tender was being produced, examination of the results by the managers may allow decisions to be made which affect the project. For example, the manager's view might be that general inflation and an anticipated increase in workload could increase the subcontract prices. In this model, this could be reflected by increasing the worst case effects on cost for the specialist subcontractor procurement to be increased from £10k to £50k and domestic subcontractor procurement increased from £10k to £25k.

Table 2: Results From Original And Revised Models

Statistic	Original	Increased Subcontract Costs
Mean Profit	175 612	157 037
Minimum Profit	58 725	27 461
Maximum Profit	256 197	251 276
Risk	0.0	0.0
Opportunity	5.9	5.6

Rerunning the Monte Carlo simulation gives the results shown in Table 2. The results show that, as expected, increasing the worst case for two risk factors reduces all three profit statistics. The reduction of the opportunity classification, from 5.9 to 5.6 shows that the system is reflecting the reduction in opportunity if the risk in the subcontract prices increases. In this case, since the uncertainty in the subcontract prices has increased the uncertainty in final profit, the management might consider entering partnership arrangements with the key subcontractors. Such arrangements would reduce the uncertainty in the total subcontract price but a premium.

4. CONCLUSIONS

The project risk model was tested on projects as their tenders were being produced. This approach to testing in a live situation confirmed the applicability of the model in practice as well as in theory.

Furthermore tests on the threshold between risk and opportunity demonstrated the concept that only through the impact does uncertainty create risks and opportunities; if our objectives changes, even if the uncertainty remains constant, the risks and opportunities will also change. The classifications systems, in addition to relating the uncertainty to the objectives, allows the management of the resulting risks and opportunities by highlighting the effect of possible management actions.

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