NUMERICAL MODELLING OF CONTRACT STRATEGY EVALUATION

Steve Eccles[1], Prof. Mike O'Reilly[2], Dr. Virginia Stovin[3]

[1]*Dept. of Civil & Structural Engineering, The University of Sheffield*
[2]*School of Civil Engineering, Kingston University*
[3]*Dept. of Civil & Structural Engineering, The University of Sheffield*

There is considerable subjective evidence that supports the view that the contract strategy which is used to procure a construction project influences the project's cost, time and quality performance. Assuming this view is correct, the client of a construction project should aim to select the contract strategy that is most likely to enable the achievement of the client's particular price, time and quality objectives. However, this selection process presents a very complex decision problem. This paper reports on a numerical model that can be used in conjunction with human expertise to assist in the contract strategy selection process. The research has focused on the price and elements of the decision problem, but the same principles could also be applied to the quality aspect. The model uses probabilistic techniques (i.e. Monte Carlo Simulation). It provides a framework which can be used to calculate the impact that different contract strategies are likely to have on a project's price and duration. The paper highlights the advantages and insights that can be gained by taking this quantitative approach to contract strategy evaluation.

Keywords: Clients' price and time objectives, contract strategy selection, quantitative assessments.

INTRODUCTION

Once a construction client organisation has decided what it wants to build it must begin to commit itself to a contract strategy. A contract strategy is the general contractual framework which must pre-define how the project is to be implemented. In a construction project the contract strategy can relate to an extensive range of factors, depending upon the level of detail, but this paper follows the example of Perry (1985) and defines each contact strategy in terms of three components:

1. The organisational structure; who is to carry out the design, the construction and the management (e.g. Traditional, Design-Build, Management Contracting, etc.)
2. The tendering process; (e.g. competitive, negotiated, one-stage, two-stage, etc.)
3. The pricing mechanism; the method of payment for the work carried out under the contract (e.g. fixed price, cost plus incentive, cost plus percentage fee, etc.)

The cost and time performances of construction projects are influenced by many different factors. Previous studies (Naoum, 1994; Songer, 1996 and others) have provided some subjective evidence to support the view that the contract strategy that is used to procure a construction project has a significant effect on the project's cost and duration.

Eccles, S, O'Reilly, M and Stovin, V (1997) Numerical modelling of contract strategy evaluation. *In:* Stephenson, P (Ed.), *13th Annual ARCOM Conference*, 15-17 September 1997, King's College, Cambridge. Association of Researchers in Construction Management, Vol. 1, 102-11.

In the New York Business Round Table Report (1982) it was suggested that five percent of project costs may be saved by choosing the most appropriate form of contract. Trench (1991) considers this estimate of five percent is an under-estimate of the savings that could be made in the United Kingdom. Regarding time savings, some contract strategies are inherently quicker because they enable the design and construction to overlap (Murdoch and Hughes, 1996).

At the beginning of a project the client organisation can define its objectives with respect to the price, time and quality performance of the project. Typically, the client's quality objectives are implicitly defined in the project specification, whilst the price and time objectives can be defined in more explicit terms (i.e. units of cost and time). The client organisation assesses its cost and time budgets to prioritise the following objectives:

- minimise price
- price certainty
- minimise time
- time certainty

It follows, therefore, that since different contract strategies have different likelihoods of enabling each of these objectives to be achieved, the client organisation should aim to select the contract strategy that is most likely to achieve its own particular set of prioritised objectives. However, this is not an easy process.

ASSESSING THE IMPACT THAT CONTRACT STRATEGIES HAVE ON A PROJECT'S COST AND DURATION

It appears reasonable to expect the client organisation to select the contract strategy that is most likely to enable the achievement of its price and time objectives. However, besides the inherent uncertainty in predicting the performance of the project, the client is unable to refer to a set of objective rules which spell out the impacts that different contract strategies are likely to have on a project. This is because:

1. it is not possible to determine the precise impact that contract strategies have had on the cost and duration of previously completed projects (Curtis *et al.*, 1991); and
2. every project and its circumstances are individual (Nahapiet and Nahapiet, 1985).

This means that the contract strategy selector must make some subjective assessment about the likely impacts that different contract strategies will have on the specific project's cost and duration (Wang *et al.*, 1996).

These subjective assessments generally derive from individuals' experiences. However, numerous experts (Ashworth, 1991: 81-98)(Perry, 1985 and others) have highlighted that these experiences can be, and frequently are, insufficient, inappropriate and prejudiced. In an attempt to provide a more rational assessment of contract strategies, previous studies have presented the opinions of widely-experienced individuals.

The conclusions from these studies tend to be general qualitative statements about contract strategies. For example, in the analysis of Management Contracting by Curtis *et al.* (1991) it was suggested that Management Contracting may reduce the construction cost relative to other contract strategies by “improved packaging of works, staged competitive tendering for works and tighter cost control”. A further example is derived from a survey undertaken by Ndekugri and Turner (1994) which reported that almost all of the 74 respondents, comprising clients, contractors and architects, indicated that Design-Build is generally faster than the Traditional method. Two main reasons were given for the difference; “First, buying, and appointment of subcontractors can overlap design. Second, in the drawing up of specifications, the contractor has a superior knowledge of the state of the industry in terms of lead times of key items of materials and components, and will usually arrange his affairs to minimise delay in their procurement”.

In a specific project, the contract strategy selector interprets these types of qualitative statements and applies them to the specific circumstances (Perry *et al.*, 1982). This paper proposes that where these qualitative assessments make reference to specific circumstances it is possible to translate the assessments from their descriptive form into actual units of cost and time.

Consider, for example, the statement obtained from the Design-Build survey (Ndekugri and Turner, 1994) about the time savings that can be gained from the contractor’s ability to minimise the delay in procuring key items. Although there is uncertainty in predicting whether a Design-Build contract strategy can save time by this means, when dealing with a particular project it is possible to use specific details such as the project characteristics, construction constraints, capacity of contractors and designers, market conditions, etc. to minimise these uncertainties and make a relatively accurate assessment of how much time could be saved, if any, by the procurement efficiency of a Design-Build contractor.

There are a number of advantages to be gained by taking a quantitative approach to contract strategy evaluation. The principal advantages include:

- The descriptive statements about the cost and time implications of contract strategies typically make reference to a particular aspect of the project (e.g. the construction cost, the pre-construction time, etc.). Therefore the decision-maker has to build up these qualitative statements to get an overall view of the impact that each contract strategy has on the project’s total cost and duration. It would be much easier to build up these statements in quantitative terms (i.e. units of cost and time) and calculate a total project price and duration for each contract strategy.
- It is possible to account for the uncertainty surrounding the subjective assessment of the contract strategies by using simple probabilistic techniques.
- The client organisation readily defines its price and time objectives in terms of cost and time units (e.g. cost budget limit, critical completion date, etc.). Thus it is possible to directly compare the quantitative assessment of a contract strategy with the client’s price and time objectives because both are measured in units of cost and time.

This paper presents a numerical model that facilitates this quantitative approach to contract strategy evaluation.

THE NUMERICAL MODEL

The model user (i.e. the contract strategy selector) must make an assessment of the impacts that different contract strategies are likely to have on each of the following cost and time elements:

- Design cost (i.e. cost of the design work that is paid by the client)
- Design time
- Construction cost (i.e. cost to the contractor)
- Construction time
- Tendering cost (i.e. cost to the client)
- Tendering time
- Transaction costs (i.e. costs to the client)

(Note: the construction cost element is described as the cost to the contractor rather than the cost to the client because, as explained later, the model requires the model user to make a separate assessment of the impact that the contract strategy is likely to have on the construction price.)

The model provides a framework where the model user can input estimates of the cost and time elements that are listed above, for different contract strategies. These input estimates will reflect the results of the model user's initial assessment of the contract strategies. Since the model uses probabilistic techniques, the model user is instructed to estimate a probability distribution (i.e. a minimum, most likely and maximum value) for each of the cost and time elements for each contract strategy that is under assessment. The model uses Monte Carlo Simulation to calculate a probability distribution of the project price and duration for each contract strategy.

The schedule of the main project activities (i.e. tender, design and construction stages) must be defined for each contract strategy to enable the model to calculate the total duration of the project for each contract strategy. For example, the schedule for a Design-Build with a competitive one-stage tender is shown in Figure 1.

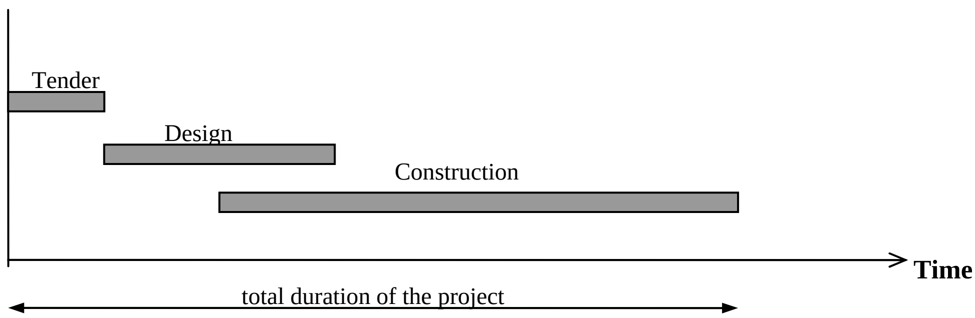

Figure 1: The general schedule of the main project activities when the project is procured using a *Design-Build with a competitive one-stage tender* contract strategy

Each type of pricing mechanism (e.g. fixed price, guaranteed maximum price, cost plus fixed fee, etc.) can be defined as a mathematical function. Thus the model can calculate the price that the client is likely to pay for each contract strategy. It is important to recognise that each pricing mechanism type is defined by a different mathematical function and subsequently the process of calculating the cost to the client is also different for each pricing mechanism type. For example, with a fixed lump sum price pricing mechanism the cost to the client is mathematically defined as a single value which is pre-defined at the tender stage and does not change (i.e. it is not a function of the actual construction cost), whereas a cost plus percentage fee pricing mechanism mathematically defines the cost to the client as the actual construction cost plus a fee that is some percentage of the actual construction cost where the percentage value is pre-defined at the tender stage.

In addition to the cost and time elements listed on the preceding page, the model user is also required to estimate the contractor’s mark-up for each contract strategy. The contractor’s mark-up for each contract strategy is estimated in terms of the relevant pricing mechanism parameter. Furthermore, because these parameters are another uncertain element the model user is instructed to estimate a probability distribution to represent to expected range of contractor’s mark-up. Therefore in the case of a fixed lump sum price pricing mechanism the model user is prompted to estimate a range of fixed lump sum price bids, whilst in the case of a cost plus percentage fee pricing mechanism the model user is prompted to estimate a range of percentage fee bids.

Figure 2 gives a basic outline of the model’s operation to calculate the impact that a contract strategy has on a project’s price and duration.

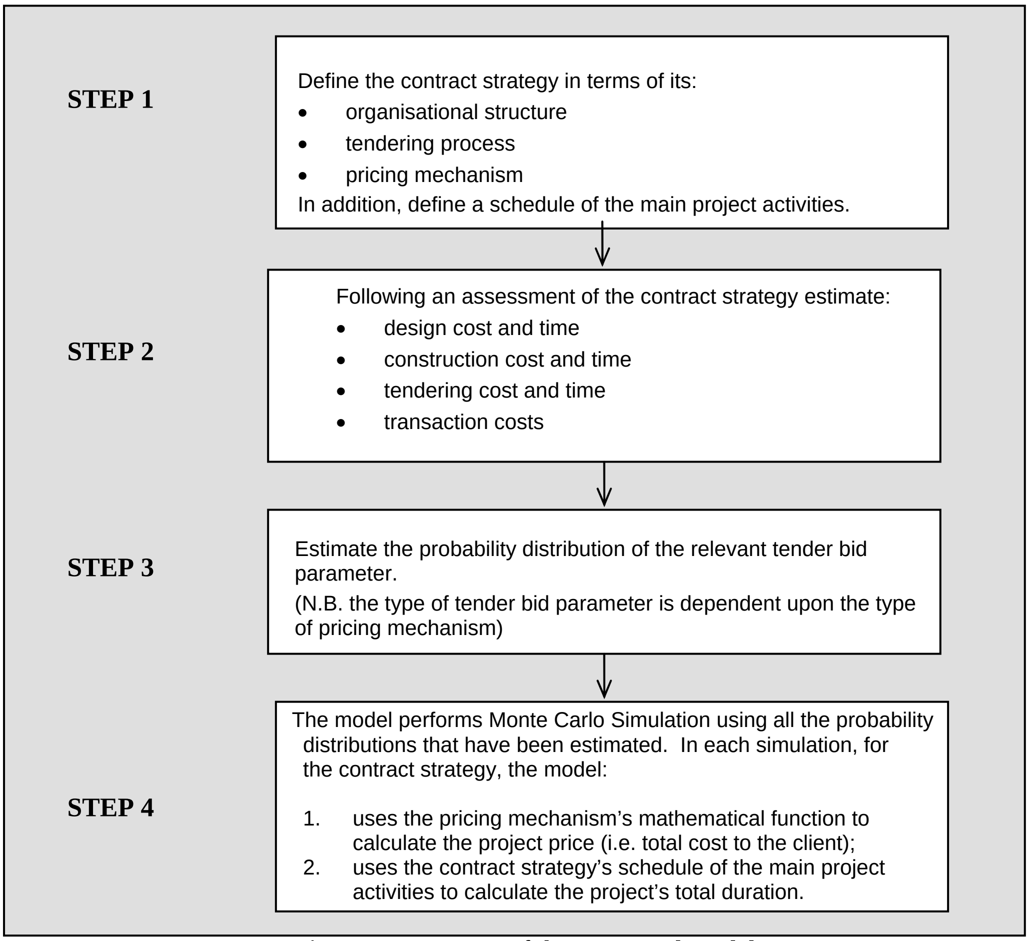

Figure 2: Structure of the numerical model

APPLICATION OF THE MODEL'S OPERATION TO AN EXAMPLE CONTRACT STRATEGY

The model's process of calculating a project price and duration is demonstrated using an example contract strategy. This example follows the same procedural steps outlined in Figure 2.

STEP 1

organisational structure: Traditional

tendering process: negotiated

pricing mechanism: cost plus percentage fee

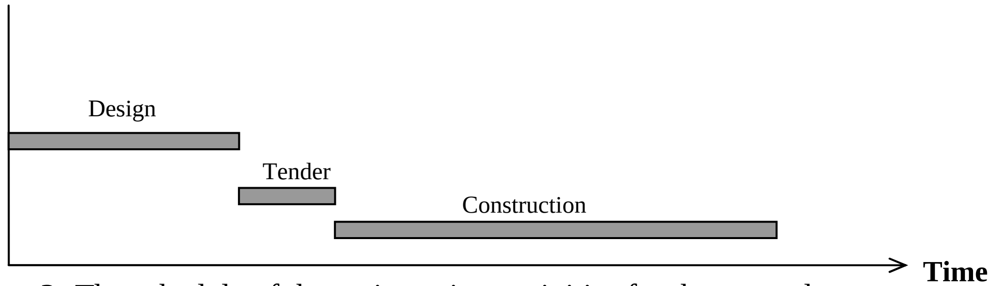

Figure 3: The schedule of the main project activities for the example contract strategy

STEP 2

An assessment of the impact that the example contract strategy is likely to have on the construction cost has led to the estimate shown in Figure 4.

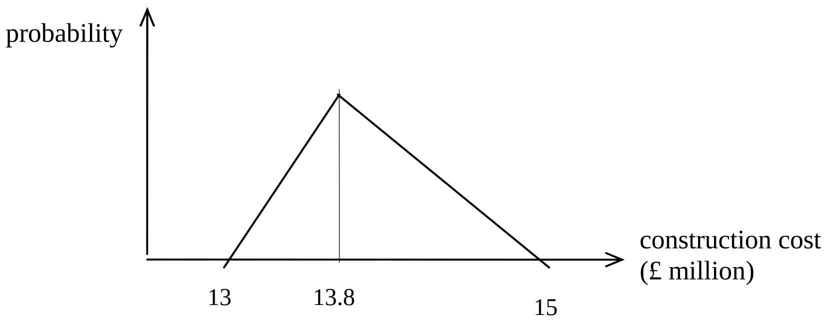

Figure 4: Construction cost probability distribution for the example contract strategy

Assume that probability distributions for the other cost and time elements have also been estimated.

STEP 3
The parameter in the pricing mechanism's mathematical function that is employed to calculate the contractor's mark-up is the percentage fee. Figure 5 shows the estimated probability distribution of this parameter.

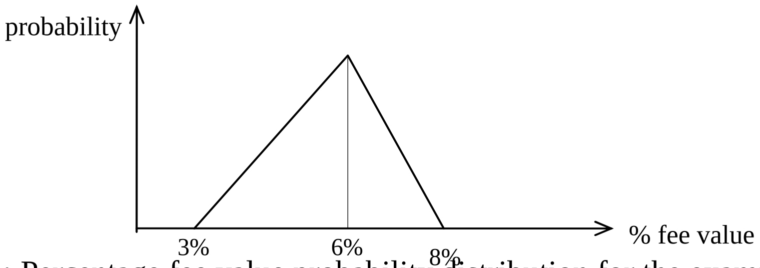

Figure 5: Percentage fee value probability distribution for the example contract strategy

STEP 4
Assume that in a single simulation run the model randomly takes the construction cost value as £14.2 million and the percentage fee value as 4%. The mathematical function which represents the contract strategy's pricing mechanism can be used to calculate the construction cost to the client.

construction price = simulated construction cost + (simulated % fee x simulated construction cost)

= £14.2m + (0.04 x £14.2m)

= £14.8 million

In the same simulation run the model randomly selects values from the other cost and time probability distributions (i.e. design cost, design time, tender cost, etc.). In a simulation run the project price is equal to the sum of all the client's costs and the project duration is equal to the sum of all the time elements. (Note: the project duration is not always the sum of all the time elements because this calculation is dependent upon the schedule of the main project activities (see Figure 3)).

The model repeats this process many times for each contract strategy that is under assessment. By performing a large number of simulations the randomly selected values from the estimated probability distributions produce a probability distribution of the project price and duration for each contract strategy.

To demonstrate how the results from the model can assist in contract strategy selection consider an example scenario where a private development company has bought an undeveloped site and has devised a detailed brief outlining a five-storey office block and site development. Assume in this example the contract strategy selector uses the model to compare two contract strategies. Figure 6 is a plot of the model's calculated results for the two contract strategies. Details of each contract strategy are presented in Figure 6.

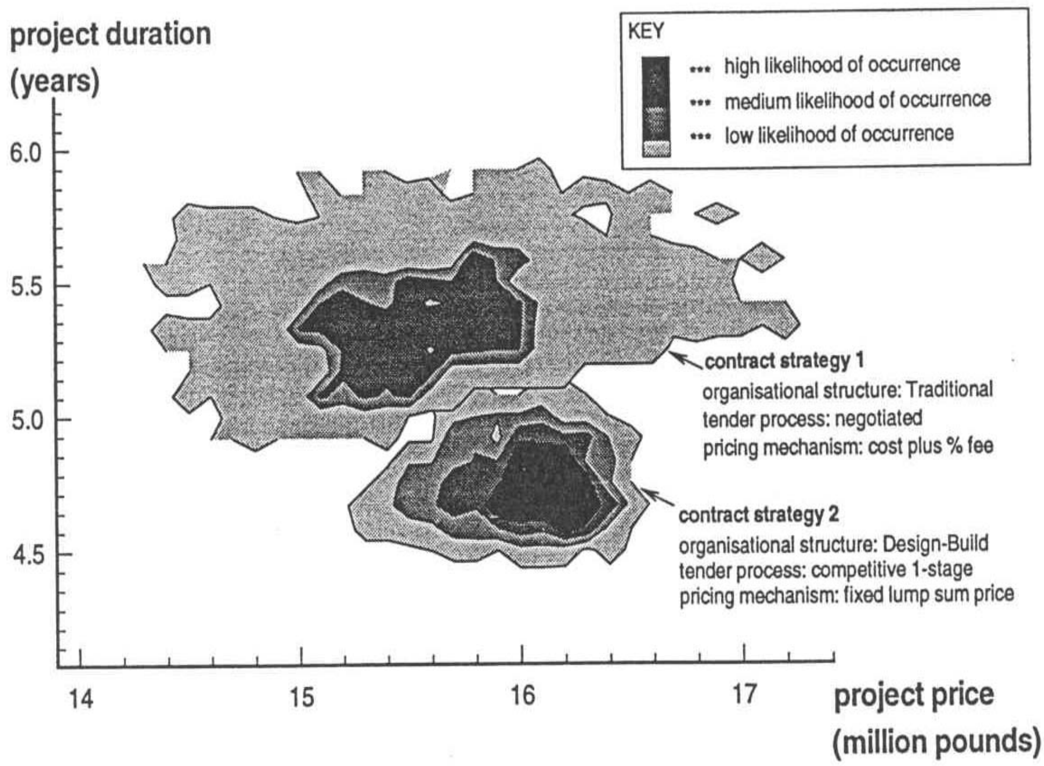

Figure 6: The model's results for two contract strategies

If the development company considers there is an opportunity in the office property market it is likely that the company's primary objective will be to minimise the project duration, in which case the Design-Build arrangement is the best option. If, however, the development company does not have any critical cost or time objective it must decide which of the two contract strategies provides the most favourable balance between the different price and time objectives. Effectively, the company must decide whether it is prepared to pay a high Design-Build price to secure price certainty as well as a short and highly certain project duration or whether it considers that the longer, less certain project duration and highly uncertain price of the Traditional arrangement is compensated by the highly probable prospect of paying a lower price than the Design-Build price.

The quantitative nature of the model's results provides the decision-maker with an explicit overview of the differences in terms of the magnitude and certainty of project price and duration. Furthermore, the model's use of probabilistic techniques enables the decision-maker to measure the likelihood of cost and time differences between the contract strategies. For example, it is possible to calculate that the Design-Build's mean project price is £0.5 million higher than that of the Traditional arrangement, but with the Traditional arrangement there is a 2% chance that the project price will exceed the Design-Build's maximum possible project price.

A particularly important measurement that the results facilitate is the likelihood that the contract strategies will exceed the client's cost and time budgets. Figure 7 displays the project duration results from Figure 6 as simplified two-dimensional triangular probability distributions. The development company's critical completion date (4.5 years) is super-imposed onto the probability distributions in Figure 7. A simple calculation determines the likelihood that the project will exceed this completion date if the project is procured using the Traditional arrangement and the Design-Build arrangement is approximately 99% and 5% respectively.

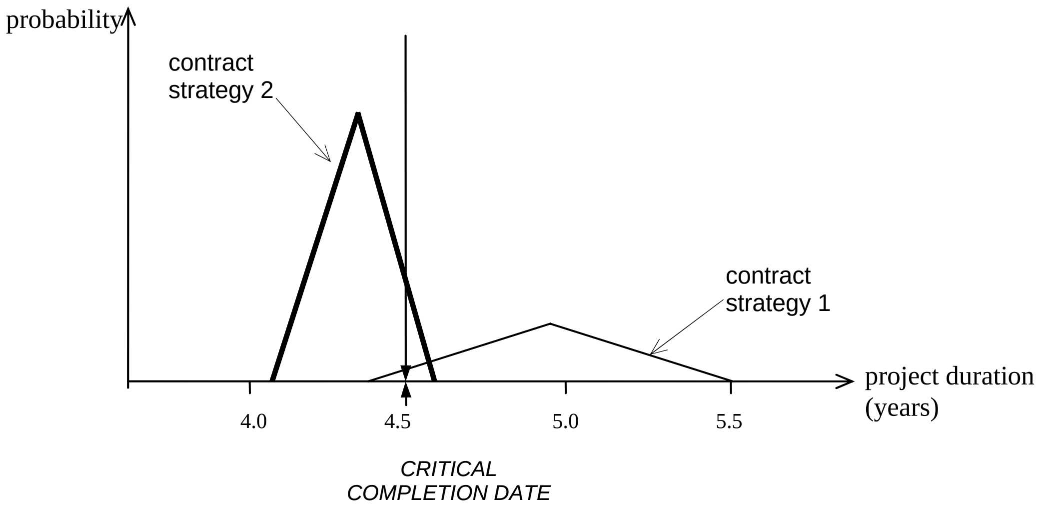

Figure 7: Comparison of the client's critical completion date with the likely project durations for two contract strategies

Although this paper describes the model as a tool which can be used to compare distinctly different contract strategy types (e.g. Traditional, Design-Build, etc.) it is also possible to compare more subtle differences between contract strategies. For example, it is possible to assess the impacts that different risk allocation strategies or different levels of client involvement could have on project price and duration.

CONCLUSIONS

The selection of contract strategies for construction projects is widely recognised as a complex decision problem. It is apparent that there is not a set of rigid and objective rules which can be used to select the most appropriate contract strategy for every construction project and consequently it is not possible to build a comprehensive decision model. There is, however, scope to improve our understanding of the contract strategy decision problem and the value of such research is reflected in the potential savings that could be made by choosing the most appropriate contract strategy.

The research proposes a new approach to the decision problem. This approach is presented in the paper as a tool that can be used to in conjunction with human expertise to assist in the contract strategy selection process. However, an underlying aim behind the development of this approach is to make the selection process more explicit. Therefore although the results that can be calculated by the numerical model are highly dependent upon the model user's expertise, this expertise must be expressed in terms of cost and time estimates and not in terms of casual intuitions.

This quantitative approach to contract strategy evaluation and selection may exert a greater pressure on experts to justify their decision processes. Consequently our understanding of the contract strategy decision problem may improve.

REFERENCES

Ashworth, A. (1991) *Contractual procedures in the construction industry*, Second Edition, Longman.

The Business Roundtable (1982) Contractual arrangements. *A construction industry cost effectiveness project report*, New York.

Curtis, B., Ward, S.C. and Chapman, C.B. (1991) Roles, responsibilities and risks in management contracting, CIRIA, *Special Publication 81*.

Murdoch, J. and Hughes, W. (1996) *Construction contracts: law and management, second edition*, E & FN Spon.

Nahapiet, H. and Nahapiet, J. (1985) A comparison of contractual arrangements for building projects, *Construction Management & Economics*, **3**, 217-231.

Naoum, S.G. (1994) Choosing appropriate construction contracting method, *Journal of Construction Engineering & Management*, ASCE, **120(**4), 687-705.

Ndekugri, I. and Turner, A. (1994) Building procurement by design and build approach, *Journal of Construction Engineering & Management*, ASCE, **120(**2), 243-256.

Perry, J.G. (1985) *The development of contract strategies for construction projects*, PhD Thesis, University of Manchester.

Perry, J.G., Thompson, P.A. and Wright, M. (1982) Target and cost-reimbursable construction contracts, Part B: management and financial implications, *CIRIA Report 85*.

Songer, A. D. (1996) Selecting design-build: public and private sector owner attitudes, *Journal of Management in Engineering*, ASCE, **12(**6).

Trench, D. (1991) *On target: a design and manage target cost procurement system*. Thomas Telford.

Wang, W., Hawwash, K.I.M., and Perry, J.G. (1996) Contract type selector (CTS): a KBS for training young engineers. *International Journal of Project Management*, **14(**2), 95-102.