THESIS CONTAINS CD ROM

QUANTITATIVE EVALUATION OF CONTRACT STRATEGIES FOR CONSTRUCTION

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This thesis is submitted in part fulfilment of the degree of Doctor of Philosophy in the Faculty of Engineering

Department of Civil and Structural Engineering

January 2000

DECLARATION

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other institute of learning.

SUMMARY

A contract strategy is, in broad terms, the legal-managerial framework adopted by the client of a construction project for carrying out that project. There is a view that projects are often procured using inappropriate contract strategies and that the associated financial consequences are significant.

Following a review of previous research, it was concluded that there was scope to develop a decision methodology that utilised quantitative techniques. A prototype model was developed to facilitate the application of the quantitative approach. The model computes probabilistic cost and time measures of a project's performance for each contract strategy that is evaluated.

Several industrialists were invited to evaluate the principles of the quantitative approach. From the fourteen industrialists interviewed, six simulated an application of the quantitative approach. Despite initial scepticism, the potential value of the quantitative approach was recognised. The six industrialists who performed example applications of the quantitative approach indicated that, in their view, the approach was workable.

In response to the findings of the empirical study, an upgraded version of the model was designed. This version also addressed several intellectual compromises which had been made in the development of the prototype model. The refined model is applied to two example projects in order to demonstrate the potential utility of the quantitative approach and also to provide guidance on how to apply the model.

It is acknowledged that the quantitative approach does not single out the most appropriate contract strategy for any given project. However, it is believed that the quantitative approach is most suited to deal with the decision problem's inherent complexities and is most likely to minimise the risk of irrational contract strategy decisions. It is therefore concluded that an improved understanding of contract strategy selection may result, especially on a personal level, from continued application of the quantitative approach.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

Special thanks are owed to Doctor Virginia Stovin, Professor Bill Anderson and Professor Michael O'Reilly (formerly University of Sheffield, now Kingston University). As project supervisors, their support and contribution of ideas was invaluable.

The support of the Engineering and Physical Sciences Research Council, in funding the research, is also acknowledged.

Finally, the author would like to express his appreciation to his family for their patience and encouragement throughout.

1. Introduction

The thesis opens with a brief description of the research subject and outlines the particular direction of investigation that was followed. The aims of the research and the structure of the thesis are outlined in sections 1.2 and 1.3 respectively.

1.1 Background to the research

A contract strategy is, in broad terms, the legal-managerial framework adopted by the client of a construction project for carrying out that project. There is no precise definition of the term 'contract strategy', nor of other synonymous terms such as 'procurement method' or 'procurement system'. Although the complete set of decisions that make up a contract strategy is unique to each project, there are certain broad strategic decisions that are common to all contract strategies. For example, ICE (1996) reported that decisions ensuing from the following questions establish the structure of a project contract strategy:

1. Should the client employ consultants and contractors, or use its own employees?
2. How many consultants and contractors are to be employed? If more than one organisation, are they to be employed sequentially or simultaneously?
3. Who is to be responsible for what?
4. Who is to bear which risks?
5. What terms of payment will motivate all parties to achieve the client's objectives?

The above questions indicate that contract strategy selection effectively encompasses all of a client organisation's decisions about how to realise its project. These decisions are made throughout the execution of a project, although some decisions have to be made immediately after a client has decided to go ahead with a project. Many decisions are interrelated and thus each decision may have an effect upon subsequent decisions. For example, the delegation of responsibility implemented at a project's outset is likely to effect the allocation of risks, which may not become an issue until a construction contractor is to be appointed. It follows, therefore, that contract strategies, in as complete a form as possible, ought to be evaluated at a project's outset (Thompson, 1983; Perry, 1985; RICS, 1995).

There is a widespread view that construction is inefficient on a number of levels, one of which is the use of inappropriate contract strategies (Latham, 1994). Since construction accounts for a significant percentage of the world's Gross Domestic Product, any efficiency gain amounts to a considerable sum. Therefore, research into the contract strategy decision problem is of great international commercial importance.

Contract strategy selection is clearly a major project decision. It is also a particularly complex decision problem because:

1. there is an unlimited number of contract strategy alternatives and, owing to the intricate nature of contract strategies, there is no standard contract strategy classification system;
2. it is widely accepted that the appropriateness of a contract strategy is dependent upon the particular circumstances of a project; and
3. the uncertainties inherent both in the project and the decision-maker's knowledge about contract strategy selection mean that the decision process is reliant upon subjective, predictive judgement.

The ultimate aim of any research in this field is to attain a set of rules that prescribe the most appropriate contract strategy for any project. However, such a set of rules appears to have remained elusive despite extensive research. Most existing contract strategy decision-aids are based on generalities derived from experiential, qualitative knowledge.

The most detailed contract strategy decision-aids are expert systems (Sodipo, 1987; Moshini, 1993; Wang *et al.*, 1996; amongst others) and models that use multi-attribute analysis (Skitmore and Marsden, 1988; Bennett and Grice, 1990; Griffith and Headley, 1997; amongst others). All of these models contain pre-formatted knowledge of some type. In expert systems the pre-formatted knowledge dictates the decision options and the mechanism used to ascertain the appropriateness of each available option from a user's responses to decision criteria. The decision criteria within all the models, including multi-attribute types, can also be considered to be pre-formatted knowledge. However, it appears that the reliance on pre-formatted knowledge inhibits the decision-maker's flexibility and consequently undermines the models' validity and utility.

It is appreciated that the decision problem has changed significantly in recent decades with the formalisation of a range of contract strategy types. Nonetheless, it is arguable that the decision problem is inherently as uncertain as when the first UK government-commissioned study into contractual arrangements was undertaken over fifty years ago (Simon, 1944).

Given that every contract strategy and every project circumstances are unique and that the range of potential contract strategies is effectively infinite, it is argued that a contract strategy decision-aid must be flexible in order to permit the specifics of each decision problem to be addressed. The user should have the freedom to evaluate any potentially viable contract strategy and the decision-aid should ensure that the user is fully aware of the particular details of each contract strategy under evaluation. It is believed that a case-specific approach would enable the particular project details, together with the uncertainty presented by individual contract strategy decision problems, to be accounted for. Furthermore, the decision mechanisms in existing contract strategy decision-aids appear to be directed by the client's preferences. For example, many decision-aids determine the appropriateness of a contract strategy according to, amongst other criteria, the client's requirements with regards to design completeness before letting the work. It appears more logical to rationalise contract strategy selection in terms of the price, duration and quality targets for a project (i.e. the client's primary objectives).

The new perspective taken in this thesis has led to the development of a novel approach to contract strategy selection. The new approach effectively requires a decision-maker to reflect his/her perceptions about a contract strategy's potential impact upon a project in probabilistic estimates of the project's constituent cost and time elements. The estimates are combined to give probabilistic cost and time measures of project performance.

To distinguish the proposed decision-aid from existing, largely qualitative techniques, it is referred to as the quantitative approach to contract strategy evaluation. The quantitative approach is considered to have several advantages, including:

- it ensures that contract strategies are evaluated on a case-specific basis;
- the decision criteria are attuned to the client's primary objectives (i.e. price and time targets) and not to the client's preferences (e.g. risk allocation preferences, price certainty, etc.);
- once a decision-maker has translated his/her assumptions about the relative appropriateness of contract strategies into estimates of a project's constituent cost and time elements, it is possible to accumulate these estimates into a prediction of the respective project's overall price and duration for each evaluated contract strategy;
- it requires the decision-maker's estimates to be explicit and hence open to debate and challenge; and
- it may enable the decision-maker to more readily identify the impact that a selected contract strategy has upon a project's performance and thereby improve the decision-maker's knowledge about contract strategy selection.

Application of the quantitative approach is described throughout the thesis from the perspective of a construction client. However, the thesis typically refers to the person responsible for contract strategy selection as the "decision-maker" rather than the "client". This is because the decision-maker may be an external party appointed to advise the client on contract strategy selection. It is also important to note that the quantitative approach could be used by a contracting organisation to manage its contractual arrangements (i.e. sub-contracts), although the thesis does not address this option.

The quantitative approach was developed specifically to aid contract strategy selection. The process of identifying and quantifying the likely impact of a contract strategy on a specific project in terms of cost and time was expected to be a demanding and novel task for experienced contract strategists. Therefore it was appreciated that the approach may be unfeasible, impractical and possibly a hindrance rather than an aid to contract strategy selection. The following section reports that the potential limitations of the quantitative approach were identified and addressed from the outset of the research.

1.2 Research aims

The research set out to identify an approach to contract strategy selection that may reduce the likelihood of procuring projects with inappropriate contract strategies. It was also intended to develop a decision-aid that may be applied in practice.

The specific objectives of the research can be summarised as follows:

1. identify and critically evaluate the methodology commonly adopted by industrialists when selecting contract strategies;
2. develop a new means of evaluating contract strategies that:

- is attuned to the nature of the decision problem (i.e. unlimited and inconsistent decision options, reliant upon subjective knowledge, case-specific, directed by the client's objectives, etc.);
- can be used by practising industrialists responsible for contract strategy decisions;
- aids the decision-maker to make rational contract strategy decisions for each individual project; and
- has the potential to improve the industry's knowledge about contract strategy selection and thus may ultimately lead to the derivation of valid and useful decision rules.

3. design and construct a decision-aid model that facilitates the application of the new approach to contract strategy evaluation;
4. obtain an empirical measure of the feasibility and utility of the new approach and the decision-aid model.

1.3 Structure of thesis

A review of the most relevant literature is presented in Chapter 2. The nature of the contract strategy decision problem is described before the industry's typical approach to the decision problem is critically reviewed. It is inferred that the industry's approach typically lacks rigour, structure or explicitness. Similar deficiencies appear to have been integrated into existing contract strategy decision-aids.

Chapter 2 concludes that deficiencies perceived to be inherent in the industry's approach to contract strategy selection might be addressed if quantitative techniques were introduced into the industry's conventional approach. The feasibility of this suggestion is supported by reported cases of comparable methods applied to contract strategy evaluation. The final section of Chapter 2 outlines the novel approach to contract strategy selection which is developed in subsequent chapters of this thesis.

Chapter 3 describes the development of a numerical model that embodies the principles of the quantitative approach to contract strategy evaluation. Chapter 3 also describes the model that was implemented in Microsoft Excel.

The feasibility and utility of the fundamental principles of the quantitative approach were tested by collecting the views of industrialists. Chapter 4 addresses important methodological issues before presenting the methods, results and conclusions of the empirical study. In addition to industrialists' opinions about the quantitative approach, the empirical study results include industrialists' example applications of the approach to hypothetical and previously-undertaken projects. These example applications were followed up by obtaining the industrialists' responses to the results generated by the preliminary version of the model.

Chapter 5 reports refinements made to the prototype model presented in Chapter 3. The refinements were designed to amend several intellectual compromises made during the development of the prototype model whilst also taking into account insights gained from the empirical study. Risk analysis techniques and net present value calculations are amongst the refinements.

The potential utility of the refined model is demonstrated by two example applications presented in Chapter 6. Finally, Chapter 7 reviews the research and outlines suggestions for further work.

2. Literature Review

The chapter examines the nature of contract strategies and the process involved in their selection for construction projects. The significance of contract strategy selection is reported and a review of existing decision-aids is provided.

The available literature on contract strategy selection suggests that the contract strategy decision problem is not addressed with the rigour and discipline that appears warranted given its reported complexity and importance. Section 2.2.4.2 introduces a range of quantitative approaches to contract strategy selection which demonstrate the potential for the development of an effective decision-aid.

2.1 The nature of a project contract strategy

A contract strategy is, in broad terms, the legal-managerial framework adopted by the client of a project for carrying out that project. The expression 'procurement' overlaps considerably with 'contract strategy', and neither of these terms are used consistently in the literature.

In order to establish the fundamental nature of contract strategies, it is useful to break them down into their key components. Perry (1985), Thompson and Perry (1992), Wang *et al.* (1996) and Kumaraswamy and Dissanayaka (1996) identified similar broad decision areas which are considered to be prevalent in all contract strategies. According to Thompson and Perry (1992) and Wang *et al.* (1996), contract strategy selection involves decisions about the following:

- number of work packages;
- organisation of the roles of the parties and their boundaries;
- terms of payment; and
- basis for selecting contracting parties.

Perry (1985) regarded these key decision areas as the "primary sub-systems of the contract strategy process". Perry (1985) listed the primary contract strategy sub-systems as:

- organisational structure;
- type of contract; and
- tender process.

Although these labels are not universal terms they are perceived, by the author, as useful and relevant terms of reference in the subject of contract strategy selection owing to the indeterminate nature of contract strategies. As a result, Perry's (1985) contract strategy sub-system labels are used throughout the thesis. This is with the exception that the label 'pricing mechanism' is used rather than 'type of contract' because Perry's choice of reference to a contract's method of payment is considered ambiguous.

A construction project is organised around a series of discrete contracts between various parties (Green and McDermott, 1996).The direct contracts between the client and other parties, particularly those related to construction work, are typically standard contract forms (Murdoch and Hughes, 1992).

The remainder of this section describes each of the contract strategy primary sub-systems. It concludes with a critical summary of typical approaches to overall contract strategy classification.

2.1.1 Organisational structure

Gilbreath (1983) reported that the decisions which dictate a project's organisational structure are those which determine the number of contracting parties to be employed, the scope of work assigned to each party, including the client, and the division of responsibility within both the internal and external organisations. It is widely accepted that the complete set of decisions which represents the design of a project's organisational structure is unique for every project (Nahapiet and Nahapiet, 1985).

The considerable amount of literature on the subject of organisational structure, not just within the context of construction, is reflected in the fact organisational theory dates back to the early 1940s (Shirazi *et al.*, 1996). A common conclusion resulting from research in this area is that there is not one single best structure. Rather, different organisational structures are appropriate for different circumstances (Mintzberg 1981; Walker, 1989).

Shirazi *et al.* (1996) provided an overview of the theories developed over the past thirty years which are relevant to organisational structures within the construction industry. Shrazi *et al.* (1996) described endeavours by Morris (1972), Thomas *et al.* (1983) and Bresnen (1990), amongst others, to identify issues which influence the effectiveness of a project's organisational structure and the means by which some authors have attempted to reduce the complex design process to a series of key decisions.

In contrast to the literature reviewed by Shirazi *et al.* (1996), most of the literature that has specifically focused upon selection of the overall contract strategy for construction projects has significantly reduced the potential intricacy of the decision process relating to organisational structure. This is because it has categorised organisational structures with respect to broad generic characteristics (Perry, 1985; Hendrickson and Au, 1989; Walker, 1989; O'Reilly, 1996 and others). The common labels used to describe a contract strategy's type of organisational structure include those listed in Table 2.1. The description provided for each category in Table 2.1 has been adapted from those of HM Treasury (1993a). Meanwhile the diagrams entitled 'contractual networks' in Table 2.1 are taken from Murdoch and Hughes (1992).

The labels listed in Table 2.1 are referred to throughout the thesis. However, it is important to remain aware that each of the labels encompasses a wide variety of organisational structures, some of which also have common reference labels (e.g. Accelerated Traditional, Develop and Build, Turnkey, Design and Manage, etc.). It may also be argued that some organisational structures cannot be classed within the broad categories in Table 2.1.

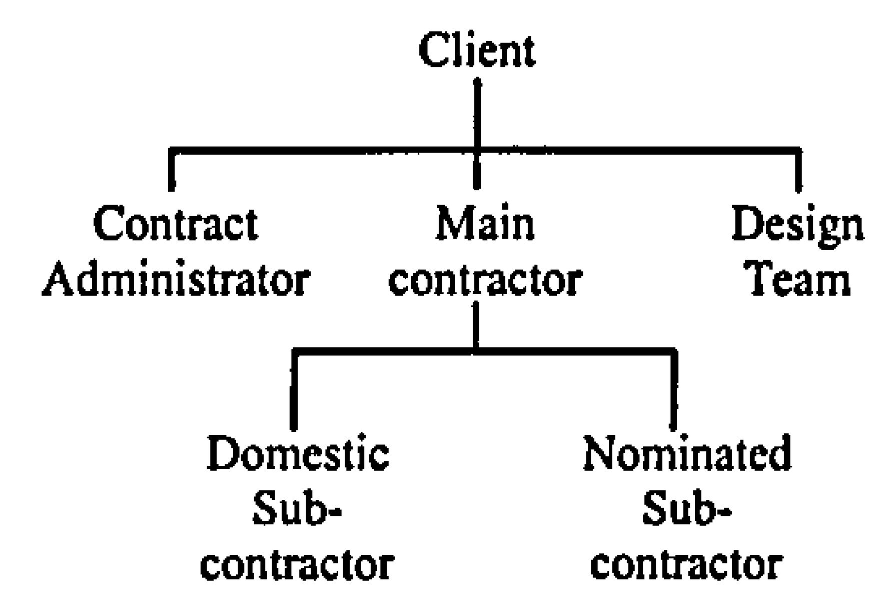
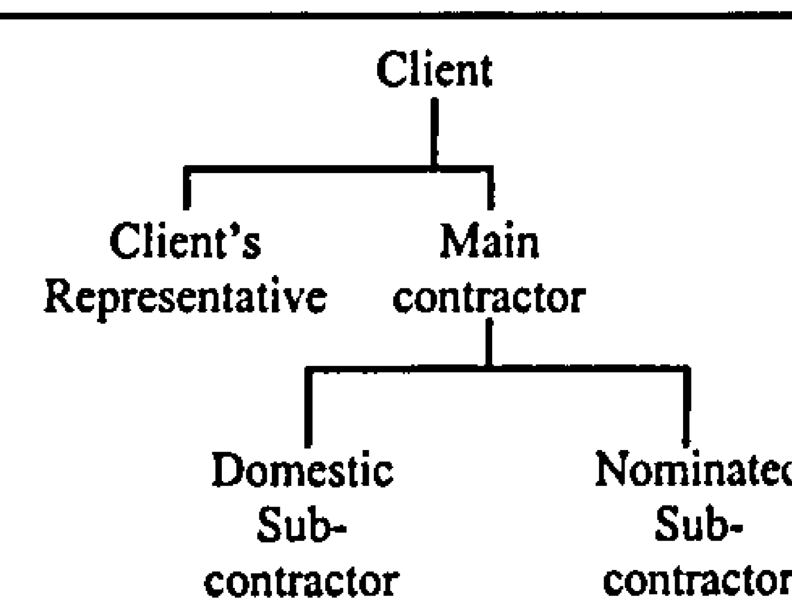
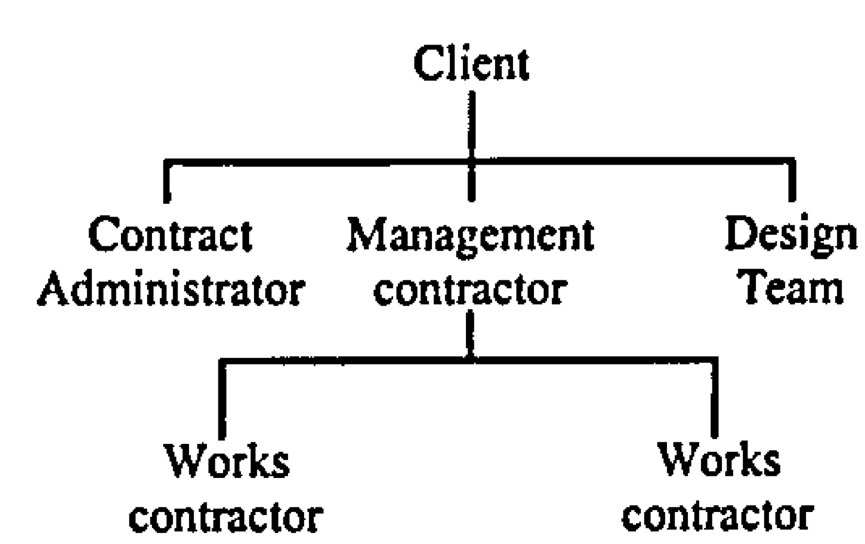
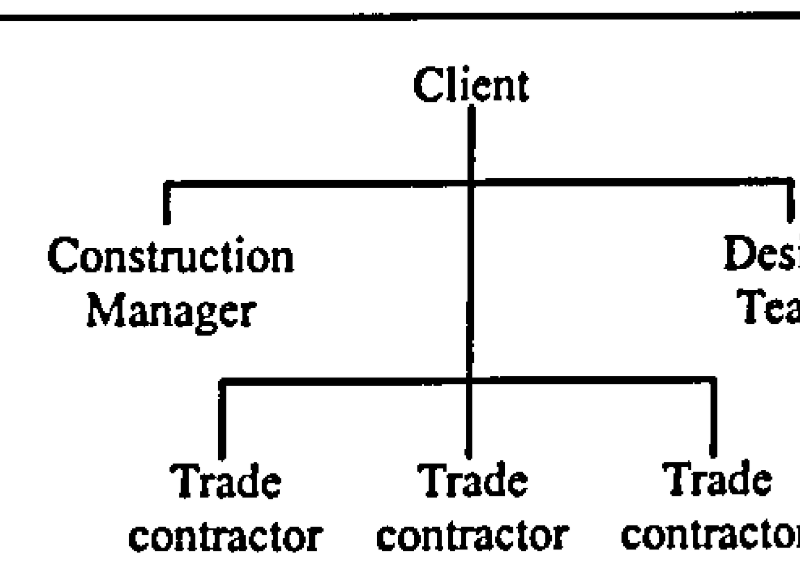
<table>
<tr><th>Organisational structure label</th><th>Description</th><th>Contractual network</th></tr>
<tr><td>Traditional</td><td>Design is completed by consultants before construction is awarded to a contractor</td><td>
</td></tr>
<tr><td>Design-Build</td><td>Both detailed design and construction performed by contractor</td><td>
</td></tr>
<tr><td>Management Contract</td><td>Design by consultants; management contractor appointed early and work package contracts let progressively by the management contractor</td><td>
</td></tr>
<tr><td>Construction Management</td><td>Design by consultants, construction manager appointed early to produce and manage work package contracts which are made directly with the client</td><td>
</td></tr>
</table>

Table 2.1 Common categories of organisational structure

2.1.2 Pricing mechanism

Gilbreath (1983) described a contract strategy's type of pricing mechanism as the method by which a price for contracted goods and services is both established and paid. Gilbreath (1983) also recognised that there is an infinite number of pricing mechanism types. Nonetheless, there are common categories into which different types can be classed. The two broadest categories are typically labelled and defined as follows (Aqua Group, 1990):

1. ***Fixed price:***
   The estimated price (determined before the respective work is undertaken) is paid by the client, irrespective of the actual costs incurred by the contractor.
2. ***Cost reimbursable:***
   The contractor is paid for the work on the basis of its actual cost.

Table 2.2 lists and describes the more specific pricing mechanism types within each of the two categories according to Ashley *et al.* (1995).

Fixed Price	**Cost Reimbursable**
Lump Sum *Single fixed price for entire contract*	Percent Fee *Contractor reimbursed for costs and a percentage of costs*
Unit Price *Payment on basis of units of work actually done. Unit costs and estimated quantities stated*	Fixed Fee *Contractor reimbursed for costs plus stipulated sum covering general administrative costs and profit*
Fixed Price with escalation *Price adjustments on cost of certain materials, labour or other factors beyond contractor's control*	Incentive Fee *Contractor reimbursed for costs while fee is dependent upon achieving certain cost or schedule targets*
Fixed Price with Bonus/Penalty for completion schedule *Bonus/penalty amount per day for early/late completion*	Performance Fee *Fee varies according to a certain agreed criteria on which the contractor is rated for performance*
Guaranteed Maximum Price *Price ceiling; bonus/penalty for cost under-runs/over-runs*	Conversion *Any type of reimbursement contract converted to a fixed price or guaranteed maximum contract*

Table 2.2 Types of pricing mechanisms (Ashley *et al.*, 1995)

Ashley *et al.* (1995) acknowledged that the fundamental difference between pricing mechanism types is the division of cost responsibility between the client and contractor. As a result, the type of pricing mechanism is considered to significantly influence both risk allocation and contractor motivation (Perry, 1986; Ward and Chapman, 1994).

It should also be noted that a contract strategy can comprise different types of pricing mechanisms because:

1. a contract strategy can comprise several prime contracts (i.e. contracts between the client and contracting party), each of which may employ a different pricing mechanism type (Gilbreath, 1983); and

2. different aspects of work executed under the same prime contract can be paid for using different pricing mechanism types (Murdoch and Hughes, 1992).

2.1.3 Tender process

Murdoch and Hughes (1992) described the purposes of any tendering procedure as to:

1. select a suitable contractor, at a time which is suited to the circumstances of the project; and
2. obtain from the relevant contractor, at the appropriate time, an acceptable tender or offer upon which a contract can be let.

A variety of tendering procedures have evolved within the construction industry in recent decades (Aqua Group, 1992). As with a contract strategy's organisational structure and pricing mechanism, the tender process may not be considered to exist as a formal system because it can constitute a complex decision process (Aqua Group, 1990).

Tendering procedures are often described in terms of their level of competition (Cook, 1991). In addition, there are widely recognised categories used to classify tender process types. According to Holt *et al.* (1995) these categories include:

- *negotiation* – the contract is awarded to a contractor after negotiation between the client and contractor
- *open* – any contractor is able to submit a bid
- *selective* – a number of selected contractors are invited to submit bids
- *two-stage* – in the first stage a contractor is selected on a competitive basis and the contract is awarded after negotiation in the second stage
- *serial* – the successful tenderer may be awarded similar contracts in the future

2.1.4 Classification of complete contract strategies

It has been suggested that contract strategies are indeterminate entities and therefore may not be considered to exist as discrete systems (Ireland, 1985). Nonetheless, the preceding sub-sections have illustrated that variants within each of the three primary contract strategy sub-systems are classified using fairly standard and widely understood terminology.

Perry (1985) highlighted the fact that some types of organisational structure are often associated with a type of pricing mechanism because they are compatible (e.g. a Traditional type organisational structure and a unit price type pricing mechanism). As a consequence, Perry (1985) claimed that contract strategies are often referred to solely in terms of their broad type of organisational structure (e.g. Traditional, Design-Build, etc.). Similarly, Hibberd and Basden (1996) asserted that decisions about contract strategies, contract forms and pricing mechanisms are commonly regarded as the same decisions.

Moshini (1993) and Haviland (1981) also perceived that contract strategy classification systems are typically over-simplified. They considered that the definition of a contract strategy is normally restricted to certain contract strategy features, whilst additional important details are overlooked. In addition, Moshini (1993) and Haviland (1981) claimed that contract strategy classification systems typically suffer from aggregation. Moshini (1993) demonstrated these perceived problems using the example organisational structure label, Turnkey. Moshini (1993) explained that although this label establishes the fact that the client holds a single contract with the developer-builder-purchaser (the turnkey organisation) there is no confirmation as to whether the turnkey organisation uses an independent design architect or undertakes construction using approaches such as construction management, single prime contracting or multiple prime contracting.

More detailed contract strategy classification processes have been proposed by, for example, Haviland (1981), Ireland (1985) and Walker (1989). Walker (1989) presented the following 2 x 3 x 7 matrix that gives forty-two alternative organisational structures:

(a) Client

- (i) No construction expertise, a senior manager liases between client and project team.
- (ii) In-house expertise available, project manager appointed within client organisation.

(b) Design team

- (i) Conventional organisation
- (ii) Non-executive project manager
- (iii) Executive project manager

(c) Contractor's appointment

- (i) selective competitive tender
- (ii) two-stage competitive tender
- (iii) competitive serial tender
- (iv) negotiated tender
- (v) management contract
- (vi) separate trade contracts
- (vii) design-and-Build (overlaps with (b) above)

Baker (1994a) suggested that the classification system proposed by Walker (1989) would not be accepted by the construction industry. Baker (1994a) perceived that industrialists related more to contract strategy labels which made reference to broad types of organisational structures, pricing mechanisms and tender processes. Section

2.3.2.1 acknowledges the view that poor contract strategy decisions can arise from contract strategy classification.

2.2 Contract Strategy Selection

Despite the existence of many standard contract forms there are no standard solutions to construction procurement and each project's individual set of circumstances need to be evaluated separately (Willis *et al.,* 1994). Different contract strategies have their own advantages and disadvantages that are relative to a client's objectives and the project circumstances (Turner, 1994; Turner, 1997). The client's objectives for a particular project are the primary factors underlying contract strategy selection (Ramus and Birchall, 1996; Latham, 1993). Hence the contract strategy selected for any project has to be that which is perceived most likely, at the time of contract strategy selection, to enable the client's objectives to be achieved (RICS, 1996). The following sub-sections describe the principles of contract strategy selection in more detail.

2.2.1 The importance of contract strategy selection

During the first half of this century construction was typically procured using Traditional type organisational structures with the works let using open tendering (Holt *et al.*, 1995). After the Second World War, construction clients came to attribute poor project performance to the project's contractual approach (Perry, 1985). This perception has remained and it is supported by numerous government-commissioned studies into the relationship between project performance and contractual arrangements. These studies include Simon (1944), Emmerson (1962), Banwell (1964), NEDO (1975), NEDO (1983), NEDO (1985), NEDO (1988) and Latham (1994).

In recent decades there has been a proliferation of contract strategy types (Cornick, 1991). McGowan *et al.* (1991) and Walker (1995) suggested that this was a reflection of the industry's, particularly the client's, dissatisfaction with existing arrangements.

Yates (1991) claimed that the cost and time impacts that may be induced by a project's contract strategy can be comparable to the impact that design and engineering advice could have upon a project's function and quality. Potts (1995) tempered this claim by acknowledging that project success is dependent upon a whole array of factors, not just contract strategy selection.

Section 2.2.4 acknowledges that any evaluation of the extent to which a contract strategy impacts upon a project is dependent upon an individual's subjective judgement. Hence there is no indisputable evidence that demonstrates that contract strategy selection is an important decision. However, there are reported cases where it has been perceived that major project problems occurred because of the selection of inappropriate contract strategies (Yates, 1991; Potts, 1995).

The New York Business Roundtable (1982) proposed that five percent of project costs could be saved by selecting the most appropriate form of contract. Trench (1991) claimed that five percent was an underestimate of the potential savings margin in the United Kingdom. In a survey conducted by RICS (1995) clients and representatives from the U.K. industry estimated that a ten to twenty percent cost saving potential was attainable by improving strategic decisions, made at the project outset, which were intended to ensure:

1. rigorous briefing;
2. value-management implementation; and
3. effective procurement method selection.

Although the third item in this list can be interpreted as equivalent to contract strategy selection, it is considered that the other two items are also integral to contract strategy selection.

2.2.2 Timing of contract strategy selection

It was reported in section 2.1.4 that Perry (1985) recognised that some contract strategy decisions are governed by other contract strategy decisions. He illustrated this point with reference to the fact that particular types of organisational structures are compatible with particular types of pricing mechanisms.

A project's contract strategy decisions are not made simultaneously. It is expected that the initial decisions relate to a project's organisational structure (Perry, 1985; Potts, 1995). Therefore, owing to the interrelationship between contract strategy decisions, early decisions ought to be based upon a holistic contract strategy evaluation. Perry (1985) asserted that if contract strategy evaluation is left too late, options are heavily constrained by irrevocable decisions and commitments. This view is supported by numerous sources that have highlighted the importance of early contract strategy selection (New York Business Roundtable, 1982; Thompson, 1983; Latham, 1994; Millar, 1995; Potter, 1995b; RICS, 1995).

2.2.3 A client organisation's objectives for its project

It is widely accepted that the client organisation's primary objectives relate to the final price, duration and quality of a project (Dobson, 1995; Turner, 1997). The three ultimate objectives are often defined as:

- Minimise project price
- Minimise project duration
- Maximise project quality

It is also commonly acknowledged that a project's price, duration and quality outcome are interrelated and may conflict with each other (Hughes and Williams, 1991; RICS, 1996). The interrelationship is demonstrated in Table 2.3. The table presents a sample of the variables that Ireland (1985) presumed have some impact on a project's cost, time and quality performance. The table indicates each variable's type of impact on each objective (increase (I) or reduction (R)) and annotates Ireland's reasons behind his assumptions.

I = Increase; R = Reduce	Effects on			
Variable	COST	TIME	Quality	Explanation
Time overlap of design and construction	I	R	R	Although the overall project duration could reduce, the actual construction cost and time is expected to increase and quality reduce
Complexity of form of construction	I	I	I	Construction complexity (e.g. unusual materials or processes) is expected to increase cost, time and architectural quality
Use of nominated subcontractors	I	I	I	Sub-contractors selected by the client or architect, rather than the contractor can lead to increased cost, time and quality.
Use of time control	--	R	R	Designs will have to be changed if they cannot be constructed within the required time. Therefore while time is reduced, so is quality
Use of cost monitoring during design	R	--	R	Designs will have to be changed if they cannot be constructed within the required cost. Therefore while cost is reduced, so is quality
Quality control on site	--	--	I	Greater degrees of quality control will increase quality, time and cost, but the cost and time effects are negligible
Competition at tender	R	I	R	Using cost as the basis for competitive tendering is expected to improve value for money, but quality and time are compromised.

Table 2.3 A demonstration of the interrelationship between a client's price, time and quality objectives (Ireland, 1985)

The interrelationship between price, duration and quality means the client cannot expect to optimise all three primary objectives. Instead, the client must establish an appropriate balance of price, duration and quality targets for the specific project. Therefore, in each project, these targets constitute the client's primary objectives.

The 'price' and 'duration' primary objectives relate to the project stage at which the works are complete. In contrast, the 'quality' primary objective concerns the project quality when the works are complete and also subsequent to that stage; when the project is in operation. For instance, Garvin (1988) listed the following eight dimensions of quality:

- performance;
- features;
- reliability;
- conformance;
- durability;
- serviceability;

- aesthetics; and
- perceived quality.

Cost and time objectives relating to project stages, other than at works completion, are often cited as client objectives. According to Perry *et al.* (1982) these include:

- certainty of final project price before construction commences;
- certainty of project completion date before construction commences;
- minimise pre-construction period;
- minimise construction cost and duration; and
- minimise life-cycle costs.

The last of these objectives, minimise life-cycle costs, could be interpreted as a derivative of the 'quality' primary objective. Garvin (1988) included durability, serviceability, reliability and performance within the list of eight quality dimensions.

The motivation behind the first four cost and time objectives, in the list taken from Perry *et al.* (1982), is considered to be correlated with the motivation to attain the client's primary objectives (i.e. completion within cost, time and quality targets). However, it is questionable as to whether the other four objectives are unconditionally conducive to the client's primary objectives. For example, consider the first two objectives in the list: price and time certainty. It is widely acknowledged that a predetermined price and duration are rarely guaranteed in construction projects (Flanagan and Norman, 1993). Hence it may be inferred that price and time certainty ought to be treated as secondary objectives which need to be rationalised in terms of the client's primary objectives. This issue is discussed in more detail in Section 2.5.1.1.

There are other cited client objectives which do not make express reference to cost, time or quality. Kumaraswamy and Dissanayaka (1996) included the following typical examples amongst an extensive list of client objectives:

- construction, design and financial risk allocation;
- need for mid-project design changes (i.e. flexibility);
- need to be involved;
- preference to assign single-point responsibility;
- preference to delegate decision-making;
- health and safety concerns;
- good communications; and
- level of price competition.

Despite the fact that many potential client objectives do not make express reference to cost, time or quality, it is evident that the issues central to these objectives have some bearing upon at least one of the primary objectives. In other words, they are subordinate to the client's primary objectives. Furthermore, like price and time certainty, they are not necessarily conducive to the client's primary objectives. Again, this issue is discussed in more detail in Section 2.5.1.1.

2.2.4 Differentiation between contract strategies

Numerous studies have been undertaken to identify which variables affect the performance of projects. Some of these studies have concluded that a project's contract strategy does not affect the project's performance. Ireland (1983), Rowlinson, 1988; Rwelamila (1994) and Walker (1994) suggested that project performance is affected by managerial actions and human factors such as attitudes and the quality of the relationships between the project participants. There are, however, opinions that these factors are not independent of the contract strategy type. For example, Perry (1995) reported the existence of views which claim that contractual arrangements can influence both contractual culture and management effectiveness. Meanwhile, HM Treasury (1993b) claimed that a project's contract strategy can influence the way in which the client organisation, the designers, consultants, contractors and suppliers work together.

Some studies which set out to ascertain the variables that affect a project's performance have cited the project's contract strategy as a contributing factor (Sidwell, 1982; NEDO, 1983; Sanvido *et al.*, 1992; Naoum and Mustapha, 1995; Hashim, 1996). It has also been acknowledged, however, that it is not practically possible to determine the precise impact that a project's contract strategy has had on the project's performance. Curtis et al. (1991) and Ward *et al.* (1991b) reported, firstly, that there are an interrelated mass of factors which influence project performance, and secondly, that the precise impact that a contract strategy had on a project's performance would be a one-off because every project's contract strategy and circumstances are unique. Nonetheless, the perception that a project's contract strategy has some effect on the project's performance appears to be widely held.

Despite the fact that every project's contract strategy and circumstances are unique, generalised characteristics of both have been used to define the relative advantages and disadvantages of certain contract strategy types (Franks, 1984; Nahapiet and Nahapiet, 1985; Perry, 1985; Ashworth, 1991; Akintoye, 1994; Naoum, 1994; RICS, 1996, amongst many others). This literature can be divided into three types:

- articles that suggest the applicability of a particular contract strategy in qualitative terms;
- articles that suggest the relative advantages and disadvantages of different contract strategies in qualitative terms; and

- articles that suggest the relative advantages and disadvantages of different contract strategies in quantitative terms.

It is also important to note that each of the above type of contract strategy review may be:

- purely theoretical; or
- the result of a survey of industrialists' perceptions.

It is not possible to review contract strategies using direct data. This is because it is not possible to conduct a experiment where identical projects, in identical circumstances, are procured using different contract strategies.

The following sub-sections feature examples of research in which selected contract strategies, or contract strategy sub-systems, have been differentiated subjectively. The first of these sub-sections (section 2.2.4.1) addresses qualitative contract strategy reviews whilst the second sub-section (section 2.2.4.2) presents details from three quantitative reviews of contract strategies. The latter are far less commonly discussed in the literature.

2.2.4.1 Qualitative reviews of contract strategies

The reviews presented by Potts (1995) and Ndekugri and Turner (1994), featured below, are both examples of articles which endeavour to suggest the applicability of a particular contract strategy in qualitative terms. Whilst the review by Potts is purely theoretical, the review by Ndekugri and Turner is the result of a survey of industrialists' perceptions. The research presented by Naoum and Langford (1987) on the other hand, is one example of the many papers which described the relative advantages and disadvantages of different contract strategies in qualitative terms.

Potts (1995) proposed that cost-reimbursable type pricing mechanisms can be more appropriate than fixed price alternatives where:

- risk analysis has shown the risks are unconventional in nature or magnitude;
- the engineer is unable to define the works clearly at tender stage, substantial variations are anticipated, or early completion takes priority;
- an increased involvement of the client and/or contractor is required or desirable;
- exceptional complexity exists (e.g. a high degree technical innovation is required); and
- an excellent, trusting relationship between the client and contractor already exists.

Ndekugri and Turner (1994) conducted a survey of contractors, designers and clients to obtain their views about Design-Build type contract strategies. The results gained from the seventy-four respondents can be summarised as follows:

- A Design-Build type contract strategy is most suited to an experienced client, particularly when the project is large and complex.
- The contribution from a Design-Build contractor during the design stage is commonly expected to induce cost savings through improved constructability of the design.
- Essentially all of the respondents suggested that projects are completed faster if a Design-Build, rather than a Traditional, type contract strategy is used. The two main time saving facets claimed for Design-Build were reported as:
    - buying, subcontractors appointment and construction can overlap design; and
    - more efficient procurement of materials and other components.
- The majority of respondents claimed that Design-Build involves less risk of litigation and arbitration compared with other contract strategy types because the Design-Build contractor accepts more responsibility.
- A clear and comprehensive brief is an important prerequisite.

Naoum and Langford (1987) reported the responses from ten construction clients who were asked to compare Management Contracting (MC) with the Traditional method of project procurement. Table 2.4 summarises the clients' responses to twelve questions.

The first two examples suggest that the appropriateness of a contract strategy is commonly regarded as being dependent upon a project's circumstances. Therefore, given the typical complexity of construction projects, each project could present a multitude of factors that warrant consideration before a contract strategy is selected. The example taken from Naoum and Langford (1987) is a very generalised review of broadly-categorised contract strategy types. The questions and responses in Table 2.4 do not make any reference to project circumstances.

The examples demonstrate that the literature, in which contract strategies are reviewed, often cites advantages and disadvantages which make express reference to the potential of contract strategy types to induce cost and time savings or losses relative to other types. Therefore the 'price' and 'duration' primary objectives of clients are often the subject of these reviews. The 'quality' objective also features in this type of literature, but the cost and time objectives are often considered more important (Rwelamila and Hall, 1995).

Question/statement	Response		
	Yes	Same	No
1. MC is riskier to clients?	6	2	2
2. Is MC more profitable to the contractors?	10	-	-
3. Does MC involve fewer claims?	3	4	3
4. Is MC more flexible?	10	-	-
5. Does MC allow an earlier start on site?	10	-	-
6. Is MC quicker?	10	-	-
7. Is MC more reliable in predicting the construction time?	9	1	-
8. Is MC cheaper?	2	4	4
9. Is MC more reliable in estimating construction cost?	6	3	1
10. Does MC provide more control for subcontractors?	9	1	-
11. Does MC exercise more control over operations?	9	1	-
12. Does MC provide a better building design?	1	1	8

Table 2.4 Responses from ten construction clients to questions about the attributes of Management Contracting (MC) relative Traditional procurement methods (Naoum and Langford, 1987)

Several of the advantages and disadvantages claimed for contract strategy types do not make express reference to potential cost and time effects. For example, Hayes *et al.* (1983) claimed that an advantage of Management Contracting was gained from improved work packaging which results from the contract strategy's facility to involve the management contractor during a project's planning stage. However, this effect is likely to have some indirect impact upon the client's primary objectives (i.e. cost, time and quality targets). This view was supported by Ward *et al.* (1991a) who integrated a list of advantages, claimed for Management Contracting from various sources, into a hierarchical framework (Figure 2.1). The framework illustrated how the attributes of Management Contracting can contribute both directly and indirectly to the client's primary objectives. Ward *et al.* (1991a) similarly illustrated how the contract strategy advantages and disadvantages, pertaining to project circumstances, impact upon the client's primary objectives (Figure 2.2).

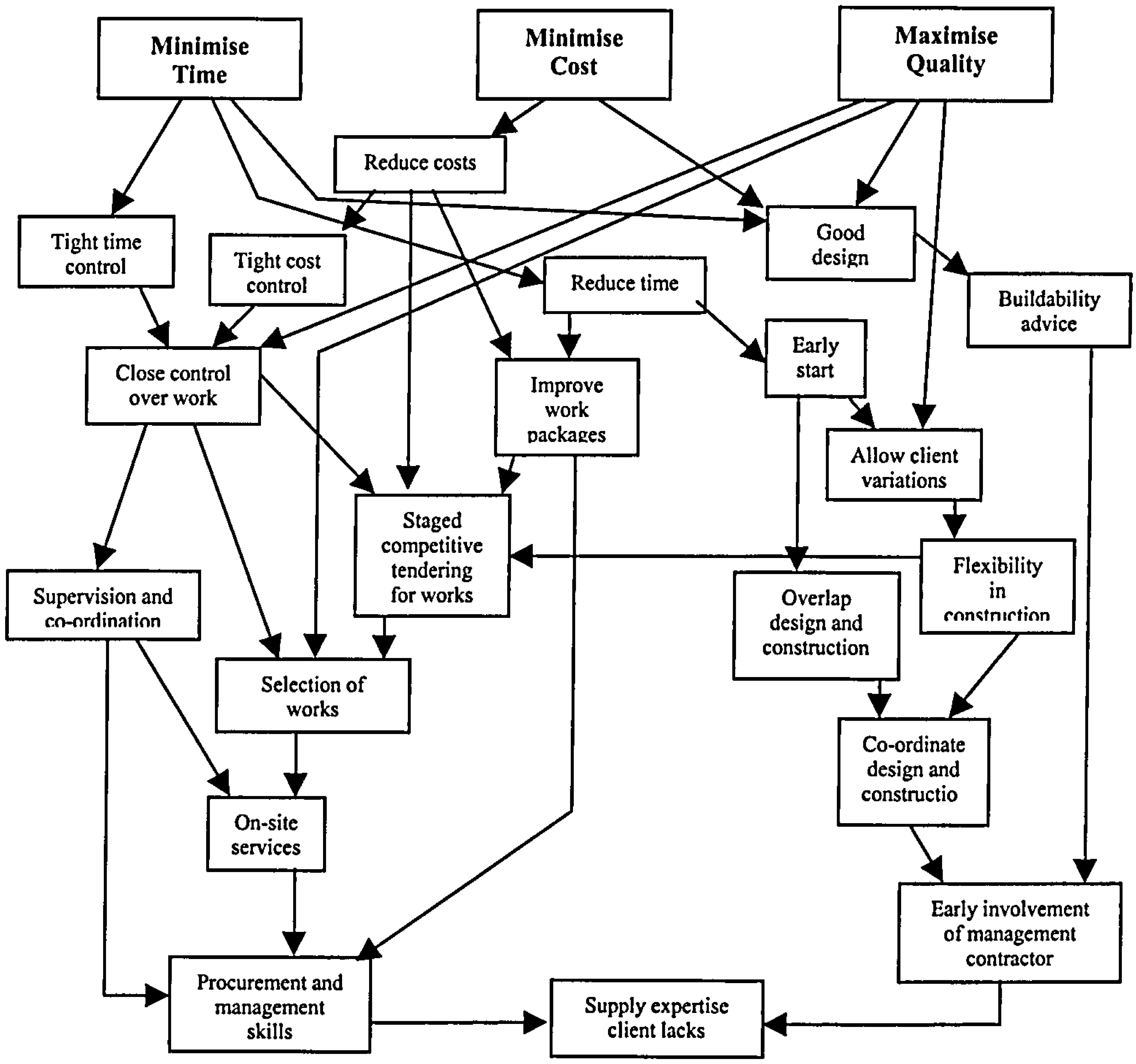


Figure 2.1 Relationship between perceived attributes of Management Contracting and a client's primary objectives (Ward *et al.*, 1991a)

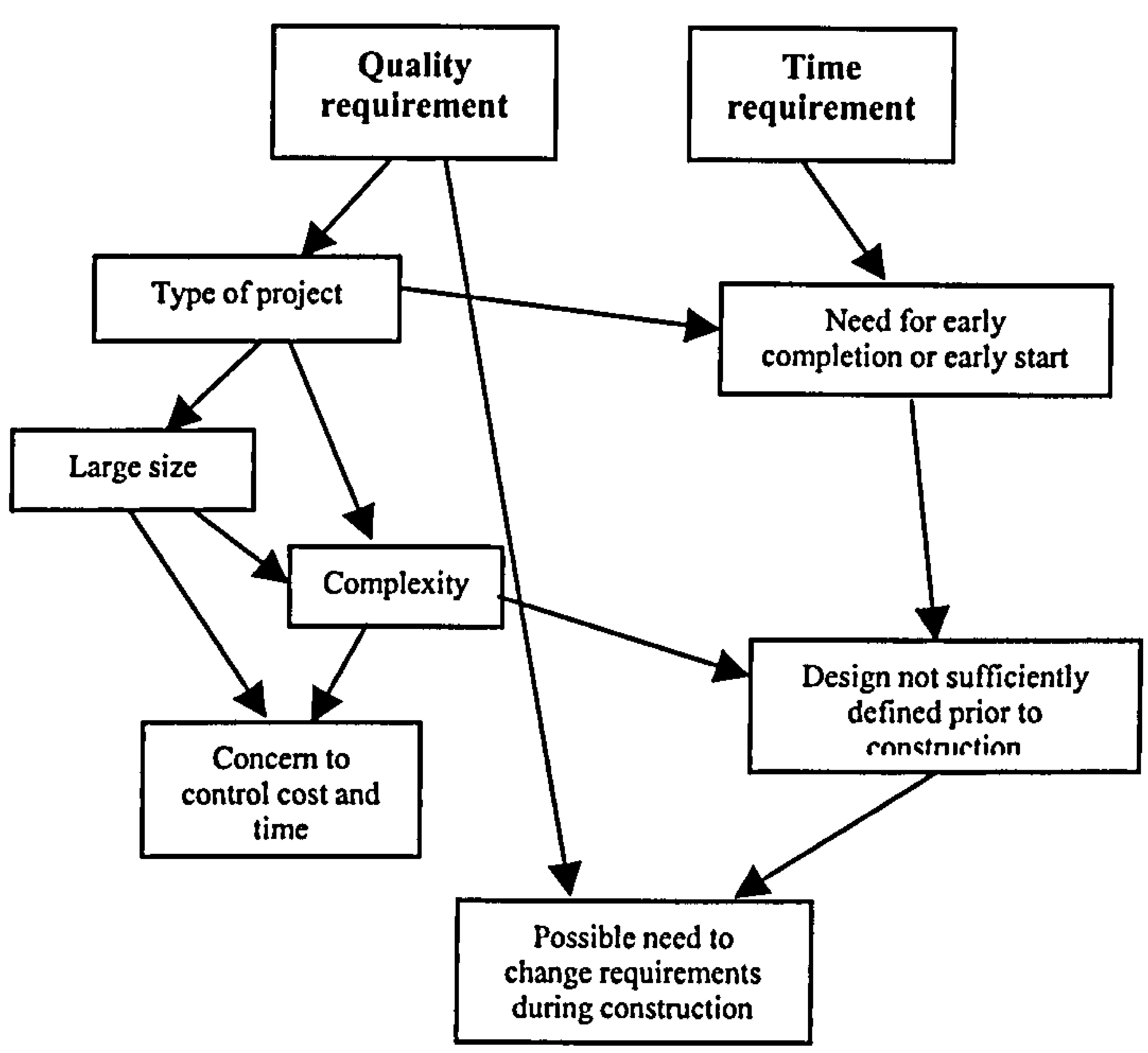


Figure 2.2 Influences of a project's nature upon a client's objectives (Ward *et al.*, 1991a)

2.2.4.2 Quantitative reviews of contract strategies

Despite the fact that contract strategies are often differentiated from each other in terms of their expected cost and time impacts, contract strategies are commonly reviewed on a qualitative, rather than quantitative, basis. Qualitative reviews of contract strategies may be considered to be the only feasible option since it has already been acknowledged that:

- reviews of contract strategies have to remain general because every project's contract strategy and circumstances are unique (Ireland, 1985); and
- assessment of the impacts that contract strategies have had on the performance of previously completed projects is based upon subjective judgement (Pain and Bennett, 1988).

The former handicap is essentially made redundant in a specific project situation whilst the latter appears to be an unavoidable obstacle. However, it may be considered possible for experienced construction professionals to quantitatively estimate the different potential cost and time impacts that different contract strategies may have upon a specific project. Three quantitative approaches to contract strategy evaluation are described below.

Pain and Bennett (1988) reported the results of a survey in which the quantity surveyor and contractor from a specific project were asked to subjectively assess and estimate the difference in project cost and contract period between two standard forms of contract. The survey prompted the respondents to enumerate the actual total cost and contract period of a project which they had previously completed using the JCT With Contractor's Design form of contract (JCT CD 81, which could be described as a Design-Build type contract strategy). The respondents were then asked to estimate the total project cost and contract period if the same project had been procured using the JCT 80 standard form of building contract (which could be described as a Traditional type contract strategy). Fourteen different projects featured in the overall survey.

It should be noted that the time estimates related to the contract period rather than the overall project duration. Therefore under the JCT CD 81 arrangement the contract period includes the construction process and an element of the design, whilst the JCT 80 arrangement covers just construction.

A fair and complete comparison between the two contract strategies' cost impacts was attained for only four projects. The estimates made by the contractors and quantity surveyors are shown in Table 2.5. With regards to the two contract strategies' time impacts, estimates were provided for twelve of the fourteen projects. Table 2.6 displays these estimates.

Project type	Case number	Total actual cost (Design-Build)	Total estimated cost (Traditional)	% difference (Design-Build relative to Traditional)
Housing	2	£581,982	£609,500	-4.51%
Education	3	£408,760	£434,260	-5.87%
Warehouse	12	£7,131,927	£7,150,000	-0.25%
Warehouse	13	£455,275	£490,000	-7.08%

Table 2.5 Comparison of total project costs under JCT 80 (Traditional) and JCT CD 81 (Design-Build) (Pain and Bennett, 1988)

Project type	Case number	Quantity surveyor's estimate of % difference in contract period (Design-Build relative to Traditional)	Contractor's estimate of % difference in contract period (Design-Build relative to Traditional)
Housing	2	0%	0%
Education	3	-11%	-10%
Education	4	0%	-10%
Education	5	-8%	-25%
Education	6	0%	-10%
Office	7	-3%	-25%
Office	9	-28%	+25%
Refurbishing	10	-17%	-10%
Refurbishing	11	+7.5%	-10%
Warehouse	12	-29%	-10%
Warehouse	13	-21%	-25%
Warehouse	14	0%	0%

Table 2.6 Comparison of the contract period under JCT 80 (Traditional) and JCT CD 81 (Design-Build) (Pain and Bennett, 1988)

The survey results suggest that a Design-Build arrangement can lead to a faster and less costly building project than a Traditional arrangement. Table 2.6 particularly emphasises the speed advantage of Design-Build given that the contract period estimates for the JCT CD 81 option includes an element of design work as well as construction.

Chisnall (1991) reported an instance where the Property Services Agency (PSA) had to select a contract strategy for a project whose client, the Ministry of Defence, desired completion in as short a time as possible whilst within acceptable constraints of cost, space and quality. The PSA team's evaluation of contract strategies involved estimates of the potential project cost and duration for each of the different prospective contract strategies. Table 2.7 shows the estimates made for four contract strategies.

Contract Strategy	Project duration	Relative project cost
Traditional fully pre-planned	3 years 3 months	100%
Accelerated traditional	2 years 10 months	101%
Two-stage develop and construct	2 years 9 months	104%
Single-stage, single tender design and build	1 year 9 months	108%

Table 2.7 Estimated project cost and duration assuming the same project was procured using each of four contract strategies (Chisnall, 1991)

The estimates in Table 2.7 display an interrelationship between project price and duration; the shorter the duration the higher the price (referred to also in section 2.2.3). This interrelationship did not exist in the data presented by Pain and Bennett (1988). This inconsistency may be interpreted either as a demonstration that the impact of contract strategies is dependent upon a project's circumstances and/or that the decision process is subjective.

Pedwell *et al.* (1996) conducted a survey in which thirty industrialists estimated the potential cost and time effects which may be induced by a contract strategy's type of organisational structure, type of pricing mechanism and facility to fast-track. All thirty respondents were presented with details of the same project ($20M complex construction project within the oil and gas industry).

The survey data were analysed using a linear multiple regression analysis. Two sets of analyses are presented in Figures 2.3 and 2.4.

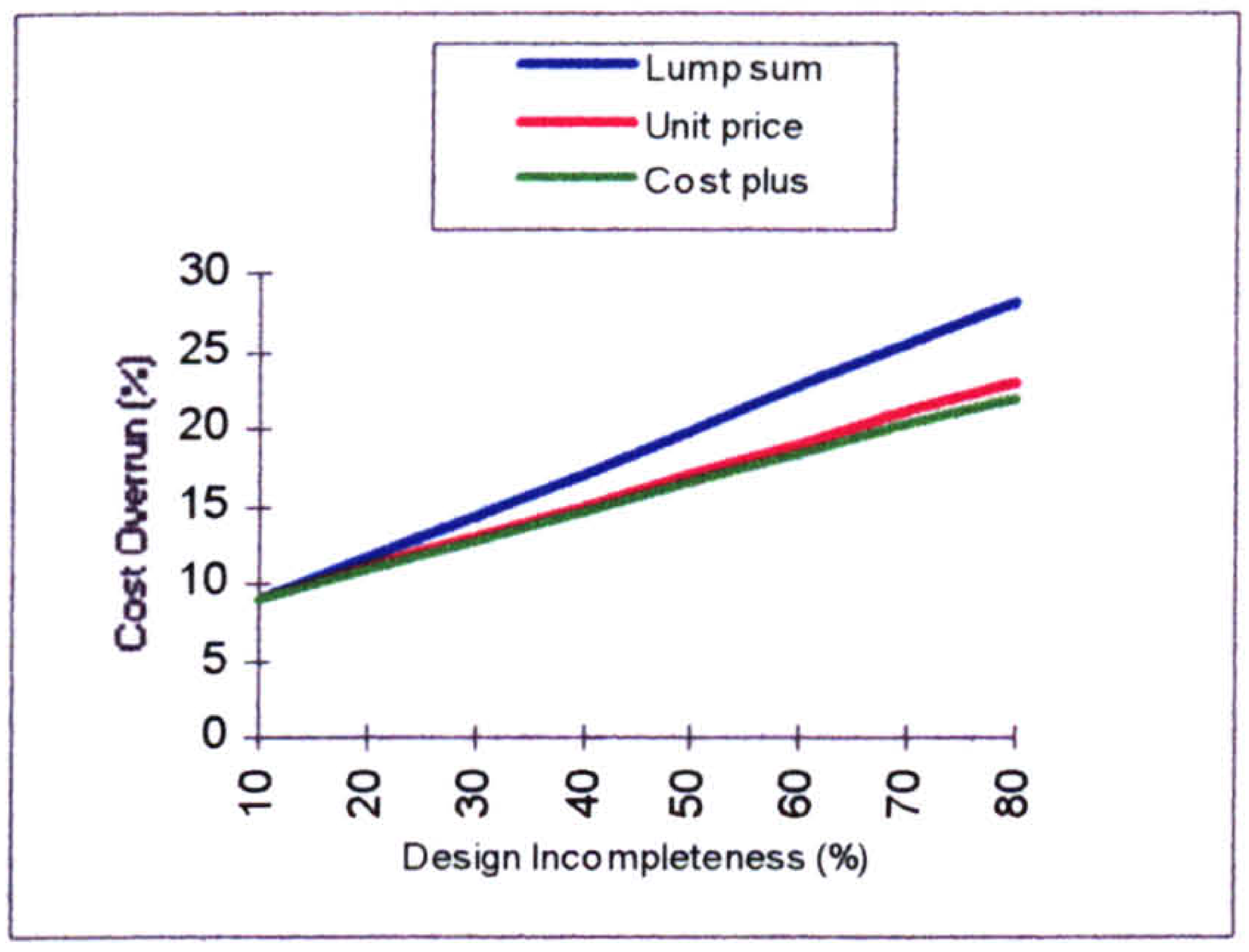


Figure 2.3 The estimated relationship between cost overruns and design incompleteness for three pricing mechanism types (Pedwell *et al.*, 1996)

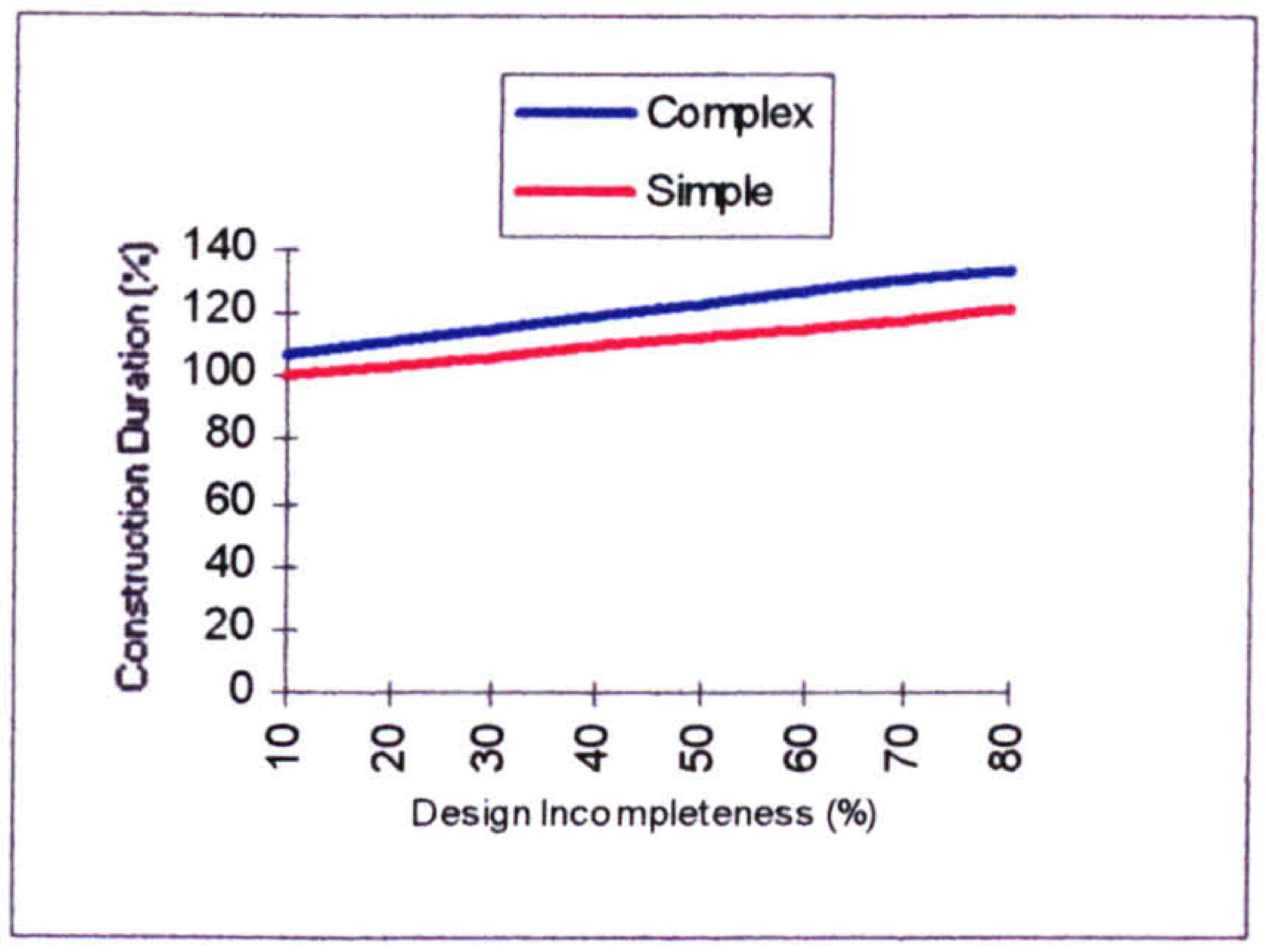


Figure 2.4 The estimated relationship between cost overruns and design incompleteness for two organisational structure types (Pedwell *et al.*, 1996)

Figure 2.3 shows the cost overruns expected at various levels of design incompleteness for three different categories of contract strategy. The three contract strategies used the same organisational structure, but each employed a different type of pricing mechanism. The contract strategies' type of organisational structure is defined as 'simple', but it was explained that this term was used to make reference to a Design-Build type arrangement. It was also indicated that a 'complex' type organisational structure assimilates to Traditional and Management type contract strategies in which there are many contract interfaces. Figure 2.4 compares the expectant effects of the two categories of organisational structure on the project's time performance at various levels of design incompleteness.

Amongst other things, Figures 2.3 and 2.4 illustrate that the impact of a contract strategy involves the consideration of interrelated factors. The figures show that a contract strategy's cost and time impacts are expected to vary according to the degree of design and construction overlap.

Pain and Bennett (1988) referred to a scenario where actual projects had been completed using a particular contract strategy and thus real quantitative data about project cost and time performance existed. Therefore the professionals' estimates of the projects' cost and time performance, if an alternative contract strategy had been implemented, were likely to be affected by their perception of actual project events. This was not the case, however, in the following two examples (Chisnall, 1991; Pedwell *et al.*, 1996). The estimates resulted from purely speculative assessments of the options' impacts upon projects that were 'to-be-completed' and hypothetical. Therefore there is some evidence to suggest that a quantitative evaluation of contract strategy options at the outset of a particular project is feasible. All three cases indicate that different contract strategies are expected to induce different cost and time performances for particular projects. Furthermore, the estimated values indicate that the difference between the impacts of alternative contract strategies can be very significant. Therefore all three examples emphasised the importance of contract strategy selection.

The quantitative comparisons of contact strategies, especially when presented using the format proposed by Chisnall (1991) are clearly valuable decision-aids because:

- the values are particular to the given project;
- the options are evaluated directly in terms of the client's primary objectives; and
- the comparisons are explicit.

2.3 Decision-making

Section 2.2 reported the principles and complexities of contract strategy selection. It is evident that it is a particularly difficult decision problem. This section addresses the biases inherent in decision-making and registers the decision-making conditions which are particularly conducive to biases. Subsequently, deficiencies in the industry's typical approach to the contract strategy decision problem are identified and described.

2.3.1 Human judgement

Decision-making is reliant upon human judgement. However, human judgements are subject to biases (Wright and Ayton, 1987). Skitmore *et al.* (1989) provided a summary of psychological literature which have addressed how these biases distort our interpretation of the past, prediction of the future and thereby our decisions in the present. Table 2.8 (Flanagan and Norman, 1993) summarises common judgmental biases and their effects.

2.3.1.1 Enabling conditions for biases

Hogarth (1980) asserted that judgmental biases can be attributed, primarily, to the characteristics of both the decision task and the decision-maker's schema (i.e. strategies, heuristics, assumptions, attitudes, etc.).

Hogarth (1980) highlighted the following four task-related factors as influential to judgmental bias:

- complexity of task;
- procedural uncertainty;

- psychological regret (i.e. personal negative consequences hanging upon the decision outcome); and
- stress.

Sections 2.1 and 2.2 indicated that the first two characteristics in the above list typify contract strategy selection. It has been established that there an infinite number of possible decision options. The decision process may warrant consideration of many interrelated factors and these factors vary on every project. Furthermore, the decision-maker is faced with considerable uncertainty. Owing to the fact that contract strategy selection takes place at an early project stage (section 2.2.2), there is uncertainty in the decision-maker's perception about what may eventuate during the execution of the project. Uncertainty is also inherent in the decision-maker's subjective knowledge about contract strategies and in the application of this knowledge to individual decision problems.

The final two characteristics in the above list could also be considered applicable to contract strategy selection because of the reported importance of contract strategy selection (section 2.2.1). Hence with respect to Hogarth's (1980) theory, contract strategy selection is clearly subject to biases.

Bias	**Effects**
Availability	Judgements of probability of easily recalled events are distorted
Selective perception	Expectations may bias observations of variables relevant to a strategy
Illusory correlation	Encourages the belief that unrelated variables are correlated
Conservatism	Failure to sufficiently revise forecasts based on new information
Law of small numbers	An over estimation of the degree to which small samples are representative of population
Wishful thinking	The probability of desired outcomes judged to be inappropriately high
Illusion of control	Overestimation of the personal control over outcomes
Logical construction	'Logical' construction of events which cannot be accurately recalled
Hindsight bias	Over estimation of the predictability of past events

Table 2.8 Common judgmental biases and their effects (Flanagan and Norman, 1993)

Hogarth (1980) condensed the schema-related conditions perceived to influence judgmental bias into:

- verdicality (i.e. the extent to which a person's understanding of the task is accurate and his/her approach is realistic);
- stability (i.e. the extent to which related decisions are approached in a consistent way); and
- generality (i.e. its applicability to a particular decision problem and thereby the capacity to account for a wide range of relevant factors).

Hogarth's (1980) theory basically appears to suggest that a rigorous and formal approach to a decision problem, particularly one which is difficult (i.e. complex, uncertain and important), is likely to lead to better decisions. According to a historical review of literature on psychology-of-judgement research by Goldstein and Hogarth (1997), there is a well established theory that intuitive judgements are generally less accurate than an analytical combination of the same information available to the decision-maker.

However, Hammond *et al.* (1997) arrived at the theory that the more difficult a decision is, the more likely the decision-maker will choose to rely solely upon intuitive judgement without the use of analytical methods. It is suspected that this theory holds true with respect to the contract strategy decision problem. The following section reports that the industry's typical approach to contract strategy selection is far from analytical. As a result, the common traits of the industry's approach as well as unsound decision policies are described as deficiencies.

2.3.2 Deficiencies in the construction industry's contract strategy selection practice

Section 2.2.4.1 described, with examples, literature that present qualitative reviews of contract strategies. Broadly-defined contract strategy types (e.g. Traditional and Design-Build) are the subject of these reviews. In addition, reference to the conditions in which these contract strategy types are appropriate and inappropriate tends to be restricted to generalised project details (e.g. high project complexity, industrial buildings, etc.). However, it is inferred that these reviews are archetypal of the industry's typical approach to the contract strategy decision problem presented by each individual project.

The reviews demonstrate that practising professionals are prepared to generalise the decision problem even though the decision problems presented by different projects can be very dissimilar. According to Evans (1982), failure to refer to specific and detailed reasoning is common when faced with complex decision problems. Furthermore, the contract strategy decision-aid models described later in section 2.4 are clearly developed around the general qualitative criteria that feature in the literature where contract strategies are reviewed qualitatively (section 2.2.4.1).

Numerous sources have reported deficiencies and weaknesses common to the industry's approach to the decision problem (NEDO, 1983; Perry, 1985; Yates, 1991; Hughes, 1994; Latham, 1994; Anderson, 1995; RICS, 1995). Although the industry has not been expressly criticised for selecting project contract strategies on a general and qualitative basis, it is adjudged that this approach is unlikely to optimise:

1. the likelihood that the most appropriate contract strategy will be selected for a project; and
2. the capacity to appreciate the actual impact that a selected contract strategy has upon a project.

Although the first of these points represents the ultimate aim of contract strategy selection at a project level, it is largely dependent upon the second point. This is because contract strategy selection is reliant upon the decision-maker's subjective assumptions which derive from his/her accumulated experience (Pain and Bennett, 1988).

The subsequent sub-sections describe the following six deficiencies perceived to be common within contract strategy selection practice:

- limited appreciation of the decision options;
- failure to set clear, realistic and balanced price, duration and quality targets;
- failure to wholly rationalise decisions in terms of the client's primary objectives;
- unstructured and imprecise decision mechanisms;
- lack of explicitness and transparency in the decision mechanism; and
- failure to account for the uncertainty inherent in contract strategy selection.

2.3.2.1 Limited appreciation of the decision options

Section 2.1.4 described common deficiencies in contract strategy classification. Both Masterman (1992) and Moshini (1993) indicated that poor contract strategy classification can have a detrimental effect on the decision process. For example, Moshini (1993) perceived that common contract strategy classification systems "allow only a partial evaluation of the strategy and offer very little scope for identifying, and then changing, those determinants that may be dysfunctional to the project goals". Section 2.1.4 also acknowledged that contract strategy options are often reduced to their standard form counterparts (Hughes, 1994; Hibberd and Basden (1996)).

2.3.2.2 Failure to set clear, realistic and balanced price, duration and quality targets

Section 2.2.3 established that a client's primary objectives for a given project constitute a balanced set of price, duration and quality targets. However, section 2.2.3 also reported that many cited client objectives do not make express reference to the client's primary objectives (e.g. a client's need to have the option to make mid-project design changes). This is regardless of the fact that these additional, secondary objectives are likely to have some impact on a project's price, duration and quality outcome and which may not necessarily be attuned to the client's primary objectives. This argument is explained further in Section 2.5.1.1.

Owing to this apparent failure to establish clear and congruent objectives and preferences, it can be deduced that the interdependencies between the client's primary objectives (see section 2.2.3) are also not taken into account. This deduction is supported by Curtis *et al.* (1991).

It is widely believed that if the client's objectives are clear and realistic there is a greater likelihood that they will be achieved (Walker, 1995; Simon *et al.*, 1997). In accordance with Hogarth (1980) (section 2.3.1.1), failure to establish clear, realistic and balanced objectives epitomise schema with low verdicality and which are therefore subject to biases.

2.3.2.3 Failure to wholly rationalise decisions in terms of the client's primary objectives

The preceding section referred to the industry's apparent failure to co-ordinate the client's preferences with the client's primary objectives. Therefore it follows that the resultant decisions are not entirely rationalised in terms of the client's primary objectives. As noted in the preceding section, this argument is explained further in section 2.5.1.1. Meanwhile this section highlights ulterior motives that occasionally govern contract strategy selection.

Perry (1985) surmised that the concept of contract strategy had not yet been widely acknowledged by the industry. Perry (1985) made reference to a report (NEDO, 1983) which asserted that Traditional type contract strategies were selected by default rather than as the result of a conscious and reasoned decision process. Similarly, Latham (1994) and Rwelamila and Hall (1995) claimed that contract strategy decision options are often constrained to those which had been implemented on past projects.

It has been acknowledged that using procedures which are familiar to the project participants can be a contributing factor to project success (Rowlinson, 1988). However, it is questionable as to whether this factor has been considered amongst the many other factors to ensure that contract strategy selection is disciplined and rational.

Yates (1991) perceived that procurement advice is often held with little regard. He claimed, with reference to two examples, that poor contract strategy selection occasionally results when the decision-making responsibility is expropriated by clients with insufficient experience and technical knowledge. However, there is a view that procurement advice, from sources external to the client organisation, could be biased by the adviser's interests (Ashworth, 1991; Pain and Bennett, 1988). Furthermore, there is a view that irrational decisions can result when the decision-maker perceives a contract strategy is 'fashionable' (HM Treasury, 1993a).

2.3.2.4 Unstructured and imprecise decision mechanisms

Again assuming that the widely-published reviews of contract strategies (discussed in section 2.2.4.1) typify the industry's approach to contract strategy selection, it may be inferred that contract strategies are normally differentiated on a qualitative basis in practice. One may even infer that the subjective assumptions used to differentiate between contract strategies, in a given project, often remain in their fairly general context (i.e. the decision-maker does not make a detailed account of case specifics). This latter trait corresponds to schema with low generality (Hogarth, 1980) (section 2.3.1.1).

The cited literature on contract strategy reviews also indicated that contract strategies are typically evaluated and compared using an unstructured decision process. Hence it would appear that a prospective set of alternative contract strategies for each project (i.e. for each decision problem) are not evaluated consistently against the same set of criteria. Again in accordance with Hogarth (1980), this reflects schema with low stability.

Following a review of British and Swedish contract strategy selection practice, Anderson (1995) reported that contract strategies are selected using non-structured, qualitative and imprecise decision mechanisms. His survey of clients and industry representatives revealed that none of the respondents employed a systematic selection process. Instead, the respondents, reportedly, based their decisions simply upon their awareness that different contract strategy types were required for different types of project circumstances. Anderson noted that the categories of contract strategies and project types are typically broad and imprecise.

2.3.2.5 Lack of explicitness and transparency in the decision mechanism

Fischhoff (1982) reported that some judgmental biases can be eliminated by making knowledge explicit. Ahmad and Morad (1993) suggested that an explicit thought process can be documented to promote communication and facilitate peer review. However, it is widely acknowledged that contract strategy selection is typically exercised as an implicit decision process (Skitmore and Marsden, 1988; Ahmad and Morad, 1993; Wong and So, 1995). In other words, the assumptions used to differentiate between contract strategies as well as the reasoning behind the assumptions are not transparent, possibly even to the decision-maker.

Curtis *et al.* (1991) conceded that it is impossible to ascertain the precise impact that a contract strategy has upon a project's performance (section 2.2.4). Nonetheless, Curtis *et al.* (1991) claimed that, relative to the industry's typical approach to project performance evaluation, there was scope to attain a better understanding of a contract strategy's impact on a project. It was proposed that in addition to establishing the tasks and objectives that a client wishes to achieve, the processes required to achieve them should be made explicit (Curtis *et al.*, 1991; Rwelamila and Hall, 1995).

2.3.2.6 Failure to account for the uncertainty inherent in contract strategy selection

Section 2.3.1.1 made reference to the considerable uncertainty presented by each contract strategy decision problem. There is uncertainty in a decision-maker's perception about what may eventuate during the execution of a project. Uncertainty is also inherent in the decision-maker's subjective knowledge about contract strategies and in the application of this knowledge to individual decision problems.

Assuming that contract strategies are typically evaluated on a qualitative basis, it is unlikely that contract strategists deal expressly with the considerable uncertainty that surrounds each decision problem. Risk analysis and management is well established as a methodology that has the potential to effectively manage the uncertainty presented by construction projects (Simon *et al.*, 1997). However, a survey by Akintoye and MacLeod (1997) reported that risk analysis and management, including risk pertaining to contractual arrangements, were implemented within only a very small proportion of the thirteen project management practices and thirty contractors who participated in the survey. The survey indicated that industrialists typically rely upon intuition, judgement and experience to deal with project uncertainty.

2.4 Contract strategy decision support

Analytical decision support refers to the techniques which are commonly classified as decision analysis and/or risk analysis. There is a wide variety of decision support techniques, but all are basically formal methodologies that embody the following analytical principles (Bernie and Yates, 1991; Goodwin and Wright, 1998):

1. break the problem down into more manageable sub-problems;
2. evaluate decision options with respect to certain criteria relevant to each sub-problem; and
3. combine the elemental evaluations to aid the decision-maker resolve the complete problem.

The ensuing sub-sections describe models that have been specifically designed to aid contract strategy selection. The models employ different decision support techniques. The models are grouped under the following headings:

- graphical aids;
- multi-attribute analyses;
- expert systems.

2.4.1 Graphical aids

Literature on the subject of contract strategy selection often includes diagrams which use a set of criteria, or even a single criterion, to differentiate between contract strategies or contract strategy sub-systems (e.g. pricing mechanisms). Figures 2.5a, 2.5b and 2.5c are common examples of graphical aids.

Figure 2.5a is a flow chart (Chappell, 1991) which presents a sequence of criteria designed to single out the most appropriate standard form of building contract. Clamp and Cox (1989) and Griffith and Headley (1997) have also presented flow charts to assist contract strategy selection.

Only one criterion is used to distinguish between the contract strategy types in Figure 2.5b (HM Treasury, 1993b). The criterion is the division of project risk between the client and contractor. Similar guides can be found in Clamp and Cox (1989) and Flanagan and Norman (1993).

Figure 2.5c is a triangular chart (Corrie, 1991) in which seven types of pricing mechanisms are arranged into a particular order to illustrate their relative attributes with respect to five different criteria. Similar charts are provided by Burgess (1980), Ridout (1982) and Bennett and Grice (1990).

These types of graphical aids are very basic and are not essentially decision support systems. Nevertheless, they demonstrate the general principles of contract strategy selection models (i.e. a set of alternative contract strategy types are evaluated against a set of decision criteria). The following section describes more elaborate graphical aids that subsequently inspired more sophisticated models.

2.4.1.1 Matrix charts

Figures 2.6a and 2.6b are common examples of matrix charts which intend to illustrate the relative attributes of a set of alternative contract strategy types. The column headings of the matrix correspond to contract strategy types while the decision criteria (i.e. attributes) operate as the row headings.

Matrix charts differ from each other in the method used to measure the perceived performance of contract strategies with respect to the decision criteria. For example,

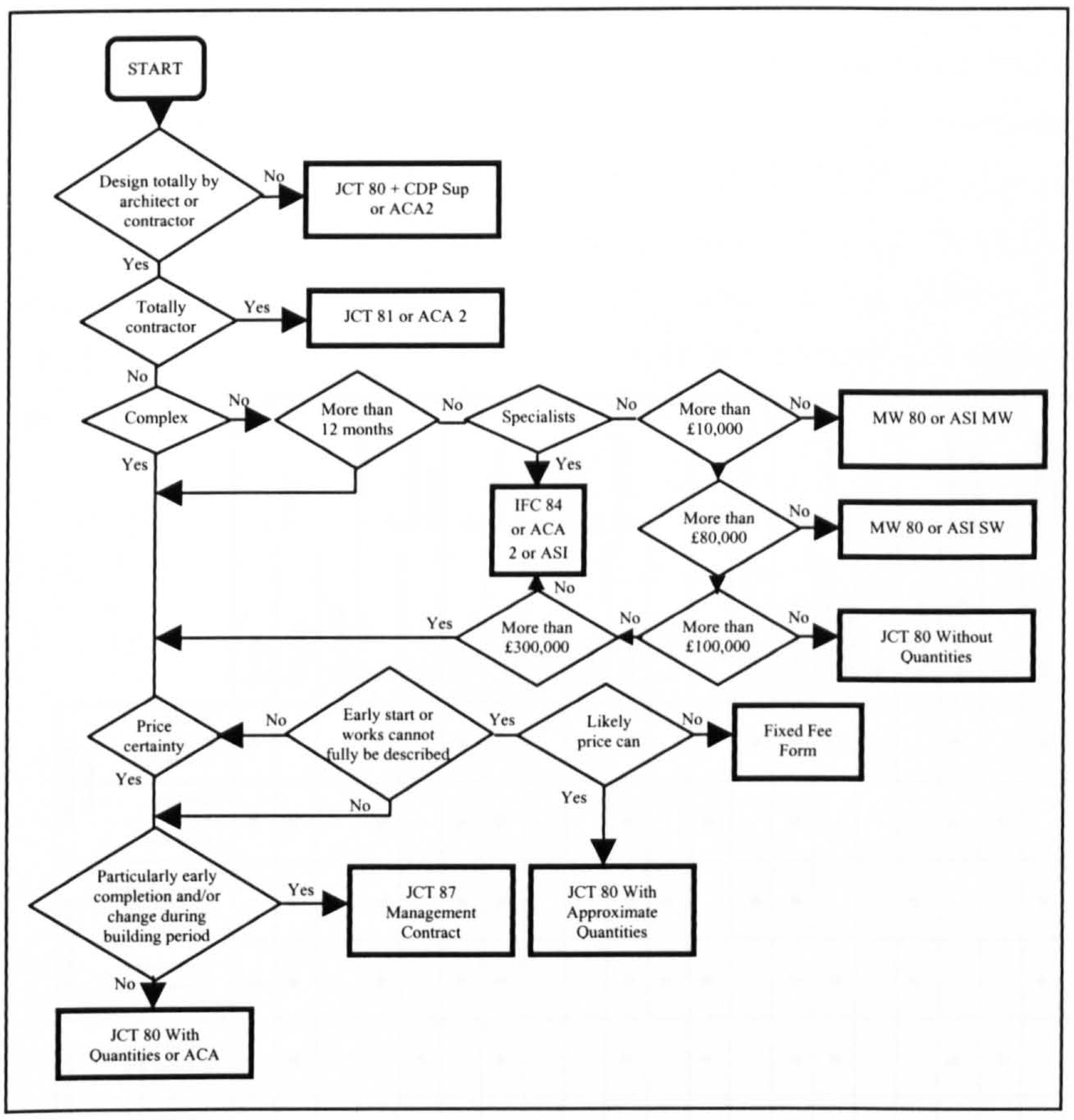


Figure 2.5a Standard form of building contract decision flow chart (Chappell, 1991)

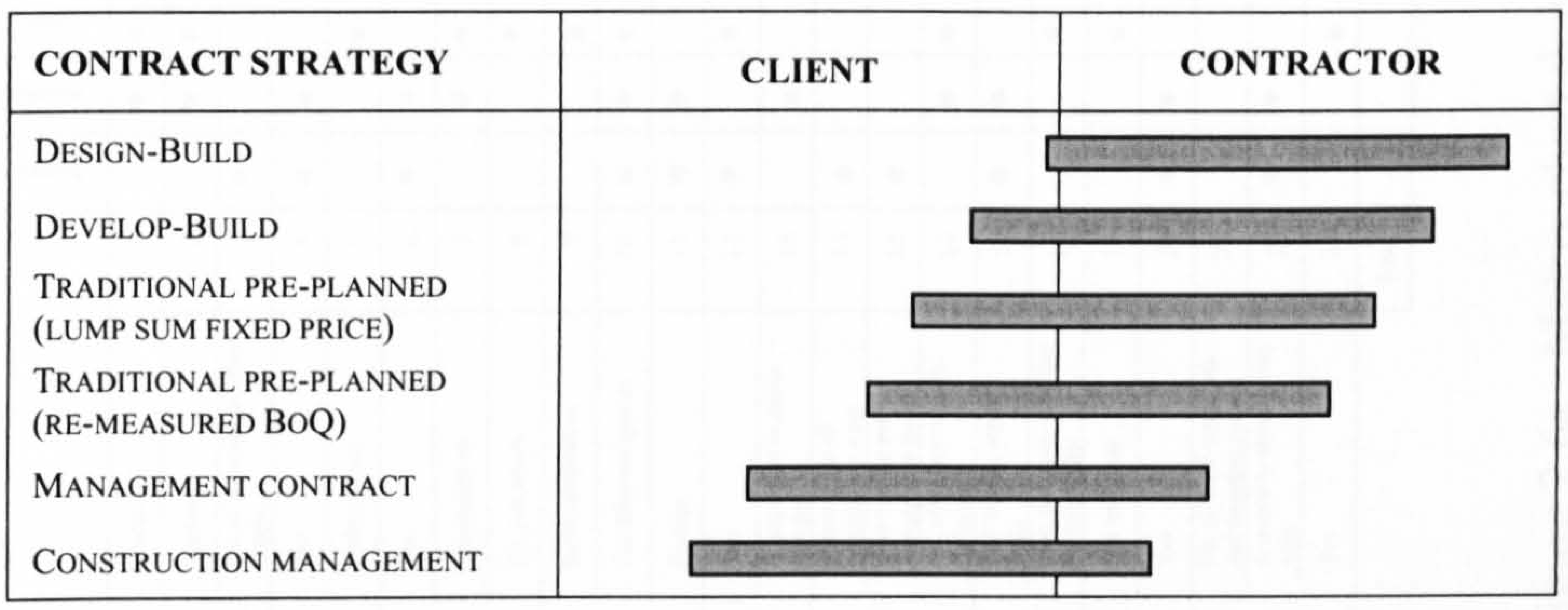


Figure 2.5b Division of project risk between client and contractor by a set of alternative contract strategies (HM Treasury, 1993b)

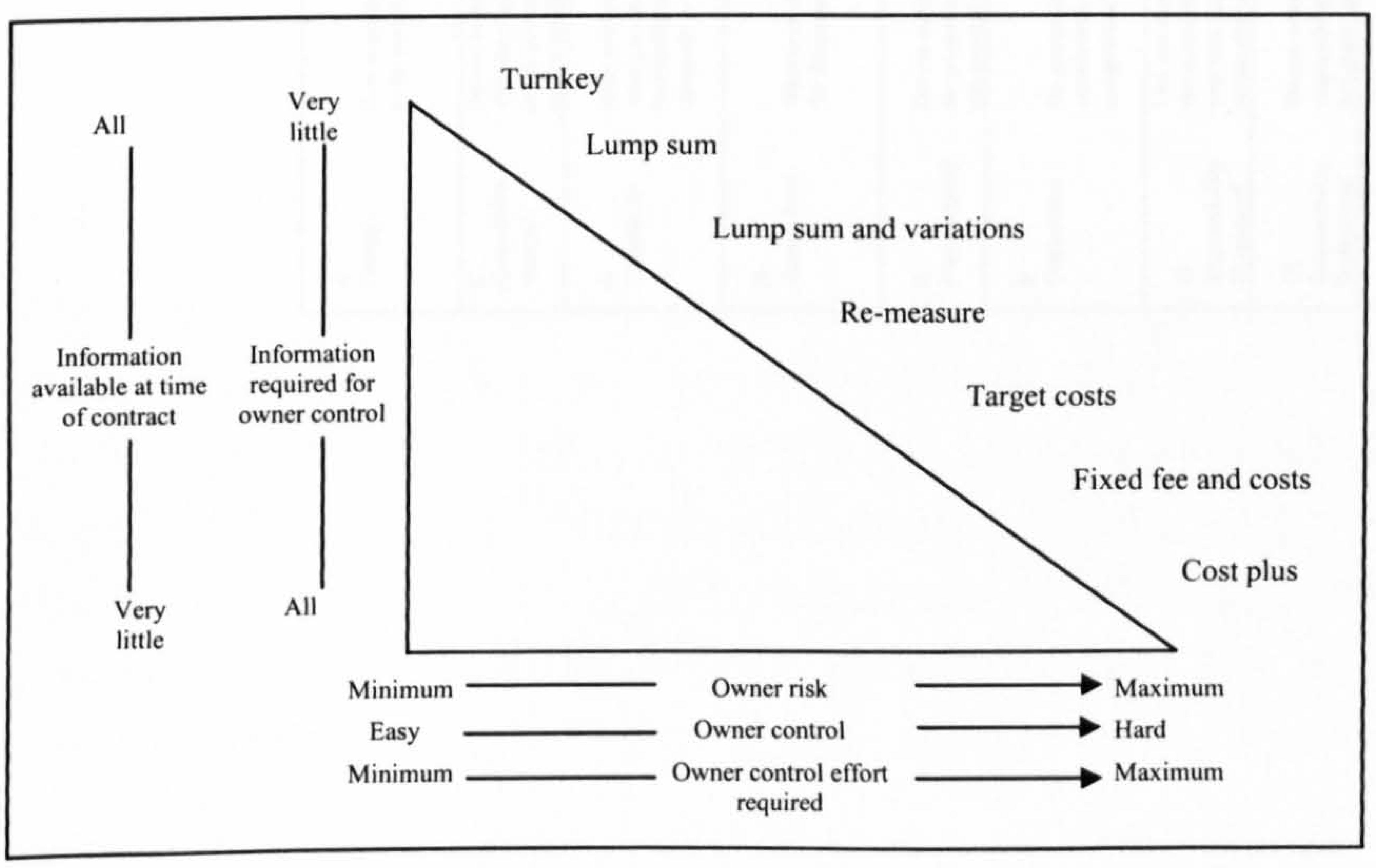


Figure 2.5c Constraints imposed by different pricing mechanism types (Corrie, 1991)

				Traditional		Design and Build			Management		Design and Manage			
				Sequential	Accelerated	Direct	Competitive	Develop and construct	Management contracting	Construction management	Contractor project manager	Consultant project manager		
A Timing	How important is early completion to the success of your project?	Crucial	1		●	●			●	●	●	●	Crucial	A Timing
		Important	2		●	●	●	●	●	●	●	●	Important	
		Not as important as other factors	3	●									Not crucial	
B Controllable variation	Do you want to foresee the need to alter the project in any way once it has begun on site, for example to update machinery layouts?	Yes	4	●	●				●	●	●	●	Yes	B Controllable variation
		Definitely not	5			●	●	●					No	
C Complexity	Does your building (as distinct from what goes in it) need to be technically advanced or highly serviced?	Yes	6	●	●				●	●	●	●	Yes	C Complexity
		Moderately so	7		●	●	●	●	●	●	●		Moderately	
		No, just simple	8			●	●						No	
D Quality level	What level of quality do you seek in the design and workmanship?	Basic competence	9			●	●						Basic	D Quality level
		Good but not special	10	●	●	●	●	●	●	●	●	●	Good	
		Prestige	11	●	●				●	●			Prestige	
E Price certainty	Do you need to have a firm price for the project construction before you can commit to proceed?	Yes	12	●		●	●	●	●		●		Yes	E Price certainty
		A target plus or minus will do	13		●					●		●	Target	
F Competition	Do you need to choose your construction team by price competition?	Certainly for all construction work	14	●			●	●	●	●	●	●	Construction	F Competition
		Construction and management teams	15	●				●	●				Construction and management	
		No, other factors more important	16		●	●							No	
Gi Responsibility Division of	Can you manage separate consultancies and contractors, or do you want just one firm to be responsible after the briefing stage?	Can manage separate firms	17	●	●				●	●			Separate firms	Gi Responsibility Division of
		Must have only one firm for everything	18			●	●	●			●	●	One firm only	
Gii Responsibility Professional	Do you want direct professional responsibility to you from the designers and cost consultancies?	Not important	19			●	●	●			●		No	Gii Responsibility Professional
		Yes	20	●	●				●	●		●	Yes	
H Risk avoidance	Do you want to pay someone to take the risk of cost and time slippage from you?	No, prefer to retain risk and therefore control	21							●		●	No	H Risk avoidance
		Prepared to share agreed risks	22	●	●				●				Share	
		Yes	23			●	●	●			●		Yes	
			Total											

Figure 2.6a Matrix chart developed by NEDO(1985)

Gordon (1994) and HM Treasury (1992) simply used tick marks and dots, respectively, to signify which criteria reflected a contract strategy's attributes and characteristics. Similarly, NEDO (1985) used dots, but divided each criterion into levels to enable a contract strategy's capacity with respect to each criterion to be rated, albeit on a very simple two or three step scale (Figure 2.6a). Franks (1984) adopted a five step scale (Figure 2.6b). The steps in Franks' chart were numerical (integers from one to five) whereas the steps in NEDO (1985) were discursive.

	Management system / Client's performance Requirements/expectations	traditional	Management contracting/ construction management	Package deal/design-and-build	Project manager/client's representative
(a)	Technical complexity; The project has a high level of structural mechanical services or other complexity	4	5	4	5
(b)	High aesthetic or prestige requirements	5	3	3	4
(c)	Economy; A commercial or industrial project or project where minimum cost is required	3	4	4	4
(d)	Time is of essence; Early completion of the project is required	2	4	5	4
(e)	Exceptional size and/or administrative complexity; Involving varying client's/user requirements, political sensitivity etc.	2	4	4	5
(f)	Price certainty; Is required at an early stage in the project's design development	4	2	4	4
(g)	Facility for change/variation control by client, users or others during the progress of the works.	5	5	1	4

Figure 2.6b Matrix chart developed by Franks (1984)

It was acknowledged in the reporting of each matrix chart that the decision criteria were to be used to establish the priorities within the client's profile of objectives and requirements. However, the models described in the following sections incorporated this process into analyses that calculate a numerical measure of the relative appropriateness of different contract strategies.

2.4.2 Multi-attribute analysis

Multi-attribute type analysis has been designed to facilitate comparison of alternative decision options with many attributes or characteristics (Keeney and Raiffa, 1976). Models which have applied this analysis type to the contract strategy decision problem have been reported by Skitmore and Marsden (1988), Bennett and Grice (1990), Singh (1990), Chan (1995) and Griffith and Headley (1997). Skitmore and Marsden's (1988) model derived from NEDO's (1985) matrix chart and this template of decision criteria and analysis has remained virtually unchanged in the subsequent models.

These models adopt the same format as Matrix charts; decision criteria (i.e. attributes) are listed as row headings while the column headings are the contract strategy types. Application of the models generally involve the following procedures:

1. The perceived performance or suitability of each contract strategy type with respect to each criterion is scored on a quantitative scale.
2. The client assigns a weight (i.e. a quantitative score) to reflect the relative importance of each criterion.
3. Each criterion's weight is proportioned relative to the sum of all the criteria's weights to give each criterion a normalised weight.
4. Each contract strategy type's criterion score is multiplied by the corresponding normalised weight.
5. The subsequent products are summed for each contract strategy type and the subsequent value reflects each contract strategy type's relative appropriateness.

Figure 2.7 shows an example application of Skitmore and Marsden's (1988) model. In the example the contract strategy which is classified as 'Design-Build Competitive' is ranked as the most appropriate option. From Figure 2.7 it is apparent that this result eventuated because the client particularly desired to:

- complete the project within a short and definite period of time;
- be guaranteed a price before the project work is executed; and
- accept very little risk.

All of the models cited above use a basic form of multi-attribute value analysis. In multi-attribute utility analysis, utility values are used in order to take account of the decision-maker's risk attitude towards the anticipated performance of the decision options with respect to each criterion (Keeney and Raiffa, 1976). A very basic version of multi-attribute utility analysis has been applied to contract strategy selection, or rather specifically to pricing mechanism type selection (Ahmad and Morad, 1993).

Figure 2.8 depicts the model analysis developed by Ahmad and Morad (1993). The analysis can be summarised as follows:

- The client assigns weights (that reflect the client's perception of importance) to each of the model's three decision criteria; project price, duration and quality outcome.
- The performance of each decision option with respect to each criterion is represented as a forecast of two discrete potential outcomes.
- The probability that a decision option will enable the achievement of each criterion's two discrete outcomes is estimated.
- Each criterion's two discrete outcomes are converted into utility values once the client's utility function for each criterion is elicited.

Client's priority questions	Client's priority rating (scale 1-20)	Rationalised priority rating	*Procurement paths* A Negotiated traditional		B Competitive traditional		C Competitive develop-construct		D Negotiated design-build		E Competitive design-build		F Management contracting		G Turnkey contracting	
			Utility factor	Result	Utility factor	Result	Utility factor	Result	Utility factor	Result	Utility factor	Result	Utility factor	Result	Utility factor	Result
1. Speed How important is early completion of to the success of the project?	20	0.25	40	10.0	10	2.5	60	15.0	100	25.0	90	22.5	110	27.5	110	27.5
2. Certainty Do you require a firm price and/or a strict completion date for the project before you can commit yourself to proceed with construction?	18	0.22	30	6.6	30	6.6	70	15.4	100	22.0	100	22.0	10	2.2	110	24.2
3. Flexibility To what degree do you foresee the need to alter the project in any way once it has begun on site?	5	0.06	110	6.6	110	6.6	40	2.4	40	2.4	40	2.4	90	5.4	10	0.6
4. Quality level What level of quality, aesthetic appearance do you require in the design and workmanship?	7	0.09	110	9.9	110	9.9	80	7.2	40	3.6	40	3.6	90	8.1	20	1.8
5. Complexity Does your building need to be highly specialised, technologically advanced or highly serviced?	3	0.04	100	4.0	100	4.0	70	2.8	50	2.0	50	2.0	110	4.4	20	0.8
6. Risk avoidance and responsibility To what extent do you wish one single organisation to be responsible for the project; or to transfer the risks of cost and time slippage?	17	0.21	30	6.3	30	6.3	70	14.7	100	21.0	100	21.0	10	2.1	110	23.1
7. Price competition Is it important for you to choose your construction team by price competition, so increasing the likelihood of a low price?	10	0.31	20	2.6	110	14.3	80	10.4	10	1.3	80	10.4	40	5.2	30	3.9
Totals	80	1.00		46.0		50.2		67.9		77.3		83.9		54.9		81.9
Rank order				7		6		4		3		1		5		2

Figure 2.7 Example application of multi-attribute analysis (Skitmore and Marsden, 1988)

- Each criterion's Expected Utility Value (EUV) is calculated from the summed products of the utility values and their corresponding probabilities.
- The decision option's EUV is calculated from the summed products of each criterion's EUV and their corresponding weights assigned at the outset.

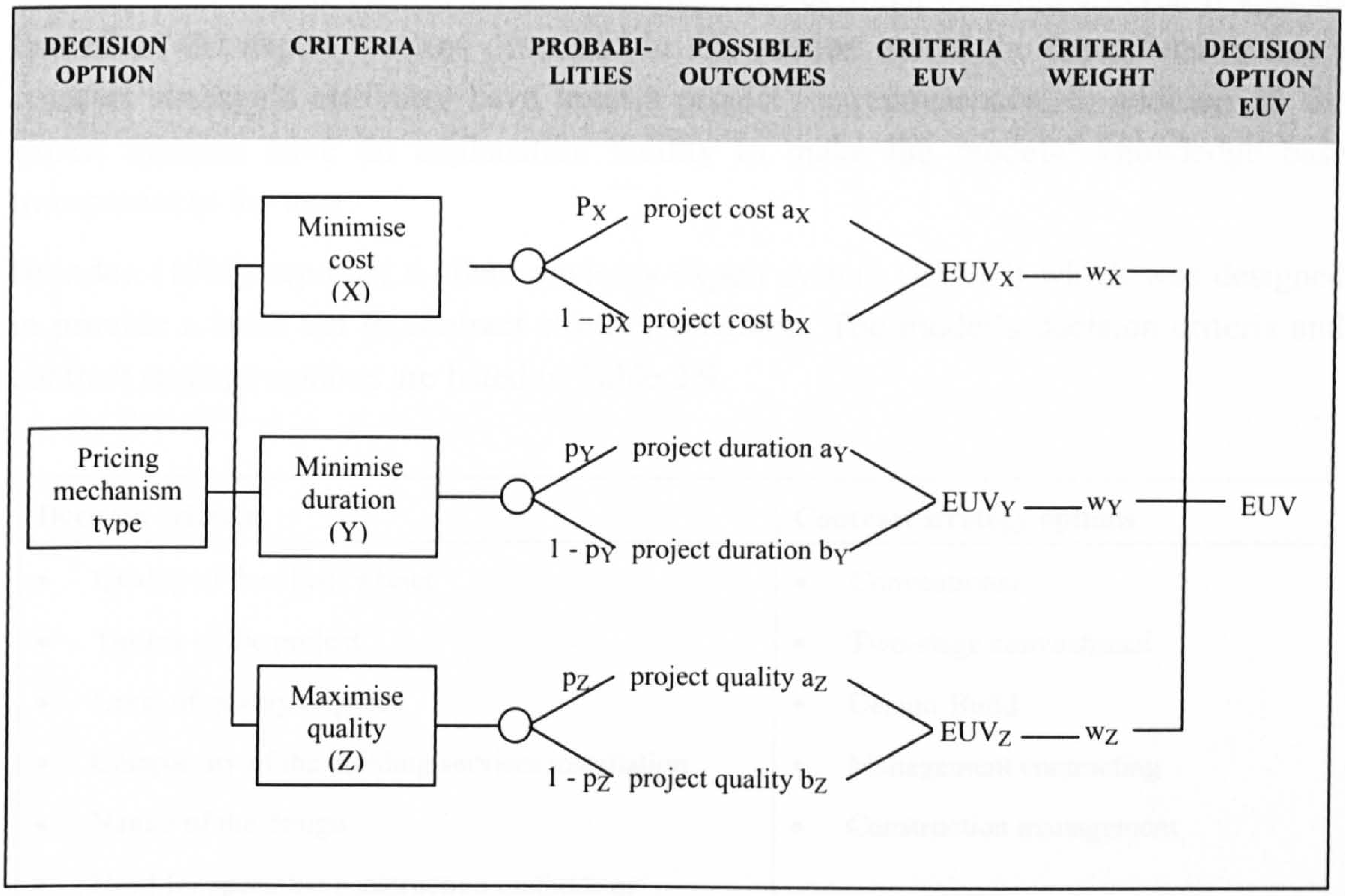


Figure 2.8 Structure of the basic multi-attribute utility analysis model developed by Ahmad and Morad (1993)

2.4.3 Expert systems

Wager (1984) provided the following definition:

"An expert system is a computer system containing knowledge in a specific area and has the ability to manipulate that knowledge in an intelligent manner such that it can be used and understood by those of more limited experience. Such systems are able to communicate decisions and advice effectively and justify their reasoning to the user"

Expert systems can be considered to comprise three main components (Pigford and Baur, 1990):

- User interface – this is the means of communication with which the user supplies evidence about the decision circumstances and subsequently receives the model output.

- Knowledge base – this is the store of experts' knowledge about contract strategies and the conditions which govern their suitability.
- Inference engine – this is the dynamic decision-making mechanism that is directed by the knowledge base.

The inference engine can model interdependencies between decision criteria. It appears that all of the expert systems described in this section model the dependencies that a contract strategy's attributes have upon a project's circumstances. In addition all the expert systems have an explanation facility to make the models' knowledge base transparent to the user.

Brandon (1990) reported a client advisory expert system (ELSIE) which was designed to provide a basic aid to contract strategy selection. The model's decision criteria and contract strategy options are listed in Table 2.9.

Decision criteria	Contract strategy options
• Quality of the client's brief	• Conventional
• Timing of the project	• Two-stage conventional
• Level of quality required	• Design-Build
• Complexity of the building services installation	• Management contracting
• Nature of the design	• Construction management
• Need for specialist construction methods or materials	
• Acceptable level of uncertainty on price	
• Need for changes during the construction period	

Table 2.9 Decision criteria and options within ELSIE (Masterman, 1992)

Moshini (1993) developed an expert system to aid selection of specific components of a contract strategy, rather than broad contract strategy types. The contract strategy sub-systems, and the options within each, are listed in Table 2.10. Figure 2.9 illustrates the structure of Moshini's model which can be summarised as follows:

1. The client responds to decision criteria relating to project constraints, construction documents, risk allocation and cost and time objectives in modules one and two (the specific decision criteria are displayed in Figure 2.9).
2. Using the decision criteria responses, the model determines a shortlist of plausible options within the contract strategy sub-systems that relate to product type, type of documentation and the responsibility and administration in the project's design and construction (see the list of contract strategy sub-systems in Table 2.10).

Contract strategy sub-system	Options within the contract strategy sub-system
Responsibility for design	• Owner • Architect/engineer • Architect/engineer/construction manager • Manufacturer/supplier • Design/builder
Responsibility for construction	• Owner • Single prime contractor • Multiple prime contractor • Design/builder
Design contract administration	• Owner • Administrative architect • Construction manager
Construction contract administration	• Owner • Administrative architect • Architect/engineer • Construction manager • Architect/engineer/ Construction manager
Basis for construction commitment	• Complete construction documentation • Scope construction documents • Outline construction documents • Performance documents
Product	• Conventional products • Subsystems • Subsystems (pre-coordinated) • Building systems
Basis for contract award	• Negotiated • Competitive, one-step • Competitive two-step
Basis for compensation	• Lump sum • Cost plus fee • Guaranteed maximum price

Table 2.10 The decision options available within the contract strategy subsystems in Moshini's (1993) expert system

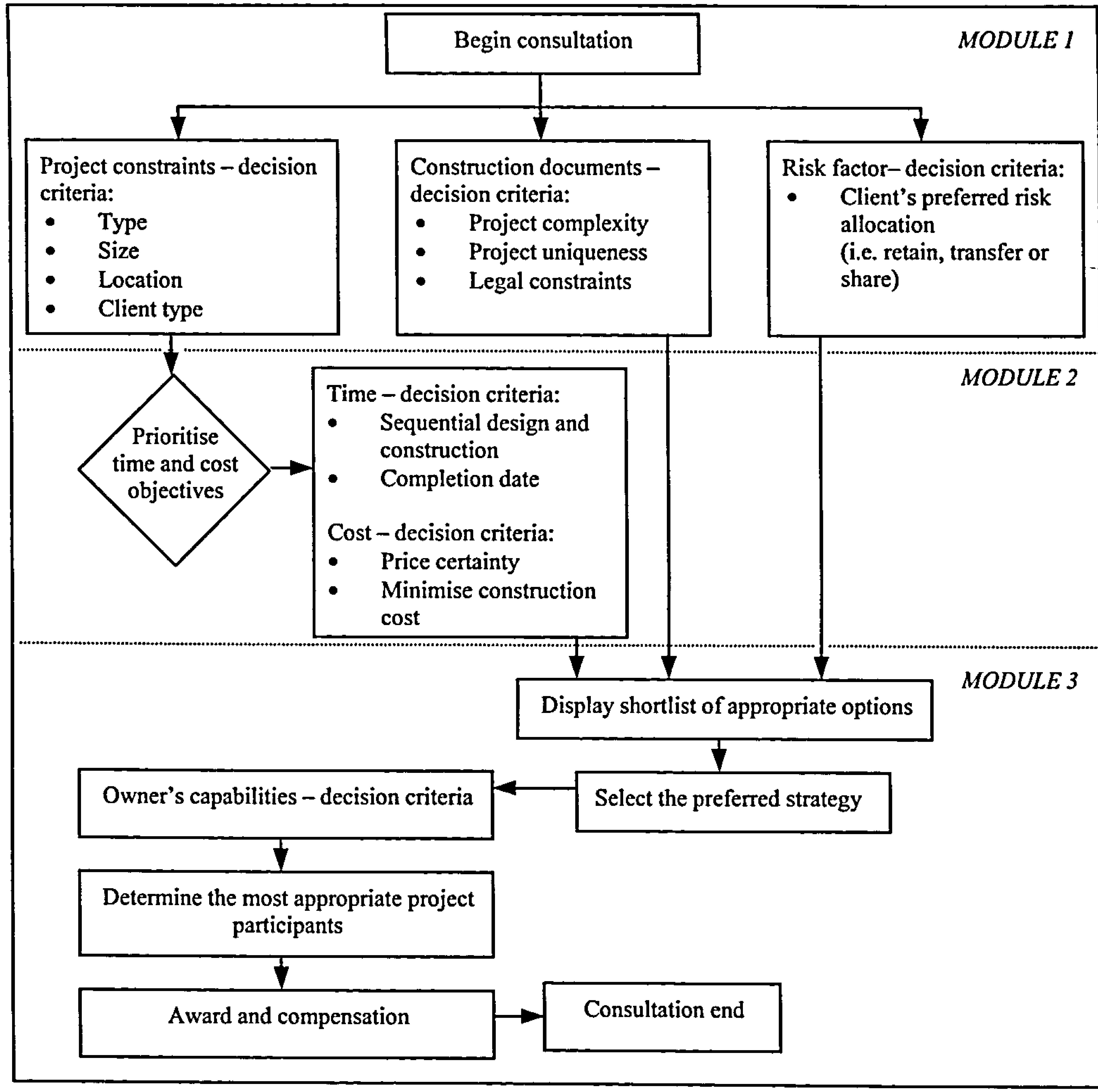


Figure 2.9 The structure of Moshini's (1993) expert system

3. The client selects the preferred strategy from the shortlist.
4. More decision criteria are presented in module three to ascertain the client's capabilities and attitude.
5. The model uses the last items of information to determine the most appropriate project participants, basis of contract award and basis for compensation.

The knowledge within Moshini's knowledge base comprises five hundred rules. Rules are sub-decisions generally expressed as IF-THEN statements (Render and Stair, 1991). The knowledge base also contains certainty factors which are probabilities used to reflect the uncertainty surrounding the rules in the knowledge base.

Wang *et al.* (1996) suggested that probability theory is not an appropriate technique to implement within expert systems designed to aid contract strategy selection. Wang *et al.* (1996) claimed that probability theory is more suited for dealing with uncertainty in the form of randomness rather than uncertainty in the form of linguistic interpretation. Consequently they proposed that fuzzy set theory was more applicable to contract strategy selection models.

Fuzzy set theory is a quantitative technique which can describe and manipulate imprecision and ambiguity (Wang *et al.*, 1996). Descriptions of the numerical operations in fuzzy set theory can found in (Zimmerman *et al.*, 1984). Contract strategy selection models using fuzzy logic have been reported by Sodipo (1987), Wong and So (1995) and Wang *et al.* (1996).

The expert system developed by Wang *et al.* (1996) is a comparatively basic model designed primarily as a learning aid for young engineers and students. The model's contract strategy options are the six main options provided by the New Engineering Contract (ICE, 1993) and although the model's complete list of decision criteria are not disclosed, an example application of the model reported in Wang *et al.* (1996) used the following criteria:

- minimise construction cost;
- price certainty;
- competition; and
- minimise risk to the client.

The expert system developed by Wong and So (1995) was instigated by research into contract decision-making in Hong Kong. The research resulted in an expert system that contained six decision criteria, six decision options and ten decision rules.

The decision criteria and options within Wong and So's (1995) expert system are listed in Table 2.11. One of the ten decision rules is provided in Figure 2.10.

Decision criteria	Contract strategy options
• Scale of project • Nature of work • Nature of client • Time constraint • Source of materials • Design of works	• simple quotation of items (no reference to any standard methods of measurement) • lump sum contract based on drawings and specifications • Schedule of rates • Management contract • Lump sum without quantities (a Hong Kong standard contract form) • Lump sum with quantities (a Hong Kong standard contract form)

Table 2.11 Decision criteria and options within Wong and So's (1995) expert system

The Management Contract option is the most appropriate when the following combination of fuzzy subsets of the criteria prevail:

Scale of project:	large, very large or very very large
Nature of work:	new substructure works or new superstructure works including specialist subcontractors
Nature of client:	private
Time constraint:	very tight
Source of materials:	innovative
Design of works:	those originated by the consultant

Figure 2.10 An example decision rule from the expert system developed by Wong and So (1995)

Sodipo (1987) used both probability and fuzzy set theory. His expert system is more detailed than the others described in this section. The model prompts the user with up to forty questions. The questions are grouped under the following headings:

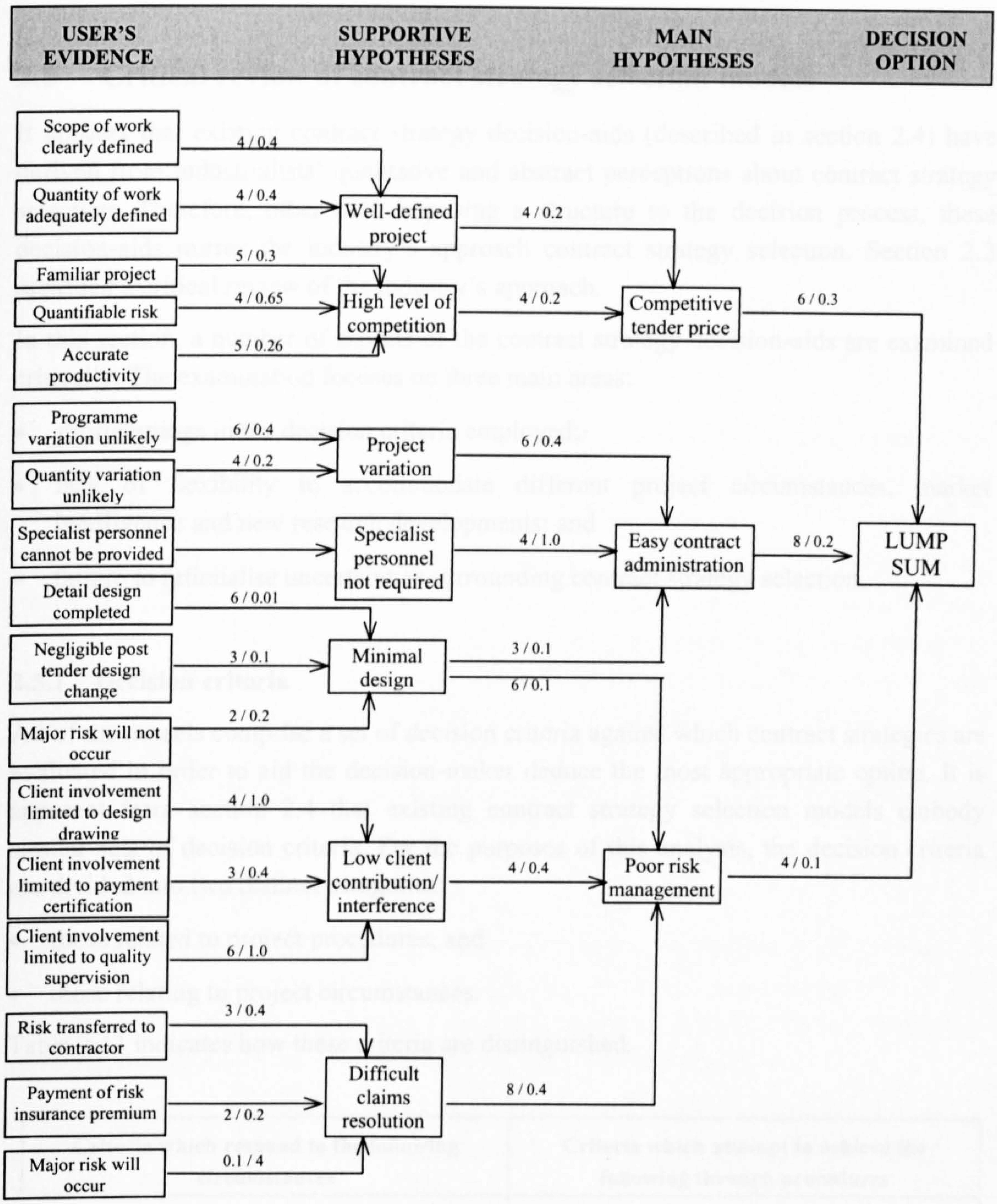
1. type of client in terms of an attitude/incentive profile;
2. expected roles of the parties to the contract;
3. level of flexibility available in, or required by, the project;
4. management procedure that the client or adviser wants to adopt; and
5. identification, assessment and preferred method of managing the major project risks.

Despite a relatively high level of detail in the inference engine, the model is limited in its decision options. The model was designed to select the most appropriate type of organisational structure and type of pricing mechanism from the alternative options listed in Table 2.12.

Organisational structure options	**Pricing mechanism options**
• Turnkey/Package deal	• Lump sum
• Conventional contract	• Admeasurement
• Target cost contract	• Target cost
• Management contract	• Cost reimbursable

Table 2.12 Decision options within Sodipo's (1987) expert system

Figure 2.11 illustrates which combination of user-inputs, with respect to the pre-defined decision criteria, satisfy the hypotheses (Main and Supportive) which in turn affirm 'lump sum' as the most appropriate pricing mechanism type.



Note:
The figures on each branch of the network are Bayesian operators LS and LN (Sodipo, 1987). They are used to reflect the relative contributions that the factors have upon the consequent hypotheses.
The higher the LS value (i.e. first value), the stronger the effect of the presence of the contributory factor on the consequent hypothesis. Similarly, the lower the LN value (i.e. second value), the stronger the effect of the absence of the contributory factor on the consequent hypothesis.

Figure 2.11 The inference network within Sodipo (1987) that affirms 'lump sum' the most appropriate pricing mechanism type

2.5 Critical review of contract strategy selection models

It appears that existing contract strategy decision-aids (described in section 2.4) have derived from industrialists' qualitative and abstract perceptions about contract strategy selection. Therefore, other than imposing a structure to the decision process, these decision-aids mirror the industry's approach contract strategy selection. Section 2.2 provided a critical review of the industry's approach.

In this section, a number of aspects of the contract strategy decision-aids are examined critically. The examination focuses on three main areas:

- shortcomings in the decision criteria employed;
- lack of flexibility to accommodate different project circumstances, market intelligence and new research developments; and
- failure to rationalise uncertainties surrounding contract strategy selection.

2.5.1 Decision criteria

All of the models comprise a set of decision criteria against which contract strategies are evaluated in order to aid the decision-maker deduce the most appropriate option. It is apparent from section 2.4 that existing contract strategy selection models embody similar sets of decision criteria. For the purposes of this analysis, the decision criteria are divided into two distinct categories:

- those related to project procedures; and
- those relating to project circumstances.

Table 2.13 indicates how these criteria are distinguished.

Criteria which respond to the following circumstances	Criteria which attempt to achieve the following through procedures
• project size, type, location, etc. • experience, capabilities and resources of project participants • external factors such as market conditions, political climate, etc.	• appropriate or desirable risk allocation • degree of active involvement by client • appropriate trade-off between likely price/duration and price/duration certainties • achieving value for money by competition • scope for client to revise the brief

Table 2.13 Two categories of decision criteria employed by contract strategy decision-aids

2.5.1.1 Decision criteria relating to project procedures

The 'project procedure' type criteria include:

- risk allocation;
- client responsibility;
- price and duration certainty;
- competition; and
- flexibility.

The above list essentially covers the 'project procedure' criteria common to all of the models described in section 2.4. The literature discussed in section 2.2.4 use these criteria to differentiate between contract strategies.

It is perceived, however, that the models' decision logic falters when these criteria are used to establish a profile of the client's objectives. This is because these objectives are subordinate to the client's primary objectives (i.e. completion within balanced price, duration and quality targets (section 2.2.3)). Consequently, 'project procedure' type criteria ought not to be regarded as client objectives. Instead, they should be evaluated in terms of their potential implications to the client's primary objectives. The following five sub-sections elaborate on this argument for each criterion featured in the list above.

2.5.1.1.1 Risk allocation

Cooper and Chapman (1987) defined risk as "exposure to the possibility of economic or financial loss or gain, physical damage or injury, or delay, as a consequence of the uncertainty associated with pursuing a particular course of action". Hence project risks present some uncertain consequences to the client's primary objectives.

There is extensive literature on the subject of efficient risk allocation which essentially aims to optimise the likelihood of achieving the client's primary objectives (Levitt *et al.*, 1980; Porter, 1981; Barnes, 1983; Thompson and Perry, 1992; amongst others). Thompson and Perry (1992) listed the following principles of risk allocation:

- Which party can best control the events that may lead to the risk occurring?
- Which party can best manage the risk if it occurs?
- Whether or not it is preferable for the client to retain an involvement in the management of the risk.
- Which party should carry the risk if it cannot be controlled?
- Whether the premium to be charged by the transferee is likely to be reasonable and acceptable.

- Whether the transferee is likely to be able to sustain the consequences if the risk occurs.
- Whether, if the risk is transferred, it leads to the possibility of risks of a different nature being transferred back to the client.

It appears that there are a variety of case-specific factors that require assessment before judging which allocation of risk, in a given project, is most likely to enable the achievement of the client's primary objectives (i.e. price, time and quality targets). Without an assessment of these case-specific factors, any decisions about risk allocation may prove to induce unfavourable consequences to the ultimate project outcome. This same argument underlies the following sections which address other decisions related to the 'project procedure' criteria.

2.5.1.1.2 Client responsibility

It is widely perceived that the role adopted by the client in a project can influence the performance of a project (Naoum and Mustapha, 1995; Potter, 1995b; Kometa *et al.*, 1996). Sidwell (1982) and NEDO (1988) proclaimed that the role in which the client is most likely to induce project success is governed by a project's particular circumstances as well as the client's experience, technical knowledge and in-house resources. Both Walker (1995) and Potter (1995b) suggested that, irrespective of a client's project management capabilities, projects benefit from clients who have a positive attitude and are prepared to involve themselves in a project to the extent that responsibilities are understood and assigned rationally and clearly.

2.5.1.1.3 Price and duration certainty

The degree of price and time certainty offered by a contract strategy is generally correlated with the degree of risk that the client transfers to other project participants (Flanagan and Norman, 1993). However, when a risk is transferred the transferee expects to receive a price from the transferor (Murdoch and Hughes, 1992). For example, to transfer risk to a contractor the client has to pay a premium to the contractor. As a result, a desire to attain price and time certainty may not be conducive to the client's primary objectives because, for example:

- the premium may be excessive (Flanagan and Norman, 1993);
- the contractor may compromise quality to save costs and time (Yates, 1991);
- the contractor may claim for extensions of time and/or additional payment arising from delay, disruption or unexpected conditions (Aqua Group, 1990);
- disputes may arise (Smith, 1996); and
- the contractor may become insolvent (Ward and Chapman, 1994).

Alternatively, price and time certainty may be attuned to the client's primary objectives if:

- the above possibilities do not eventuate;
- the contractor is more capable than the client to manage the risks (Thompson and Perry, 1992); and
- the contractor is motivated to work efficiently and cost effectively (Chapman and Ward, 1994).

2.5.1.1.4 Competition

Competition is commonly perceived, in practice, as an efficient means of obtaining value for money (Smith, 1986; Ward and Chapman, 1994). However, this may not be true in all cases. Competition can lead to over-optimistic tender bids which prove unattainable (Latham, 1994; Smith, 1995). As a consequence, the contractor may attempt to recover costs by compromising quality, pursuing claims or alternatively the contractor may become insolvent.

2.5.1.1.5 Flexibility

Gordon (1994) acknowledged that a client's flexibility needs (i.e. capacity to make changes during, or offset decisions until, the construction process) is often affected by project constraints (e.g. the occupier is unknown, delays in permit requirements, considerable project uncertainty, etc.). In which case, maintaining project flexibility is likely to be conducive to the client's primary objectives. However, Gordon (1994) and Akinsola *et al.* (1997) insisted that clients' indecisiveness can also inflate flexibility requirements. This unnecessary preference for flexibility has been widely condemned as a source of disruption, disputes and claims (Latham, 1994; Dobson, 1995).

2.5.1.2 Deficiencies in the models' decision mechanisms that arise from the 'project procedure' type criteria

All of the existing contract strategy selection models contain decision criteria that make express reference to a client's primary 'duration' and 'quality' objectives. Only a few models (Sodipo, 1987; Ahmad and Morad, 1993; Moshini, 1993) include criteria that make reference to a client's primary 'price' objective. The majority of the models include the decision criteria featured in the preceding section (section 2.5.1.1). However, some of the models contain fixed relationships between a user's responses to the 'project procedure' criteria and the likely fulfilment of the client's primary objectives. For example, in Skitmore and Marsden's (1988) multi-attribute model, the decision criterion 'price competition' is referred to as a factor that unconditionally increases the likelihood of attaining a low price (see Figure 2.7).

The preceding sections argued that generalisations of this type are not valid in all circumstances. From all the existing decision-aids, this theory is only upheld by the expert systems. However, when a user is prompted to respond to the 'project procedure' criteria, none of the models acknowledge the relevance of project circumstances. This is because the models commonly frame 'project procedure' type criteria as questions. They, therefore, encourage clients to impart their preferences without accounting for, at least explicitly, the implications of their criteria-responses to their primary objectives. The following list of questions targeted at clients typify the models' 'project procedure' type criteria:

- Do you need to choose your construction team by price competition? (NEDO, 1985)
- To what extent do you wish one single organisation to be responsible for the project and transfer the risk of cost and time slippage? (Skitmore and Marsden, 1988)
- What is your preferred allocation of the project's major risks (retain, share, transfer)? (Moshini, 1993)
- What level of design-construction overlap will be carried out? (Sodipo, 1987)

It is argued that the answers to these questions ought to be the output from contract strategy selection models, not the input. The criteria described in section 2.5.1.1 are referred to as 'project procedure' type criteria because they relate to procedural options which, if applied in appropriate circumstances, may enable the client organisation to achieve its price, time and quality targets. As a consequence it is necessary to undertake a thorough evaluation of a project's circumstances before deciding to implement a particular procedural option.

2.5.1.3 Deficiencies in the models' decision mechanisms that arise from the 'project circumstances' type criteria

The 'project circumstances' type criteria are perceived as those which relate to the constraints imposed by:

- a project's characteristics (e.g. type, size, location complexity, risks, etc.);
- the capabilities of the project participants (i.e. the client and potential contracting parties); and
- external factors (e.g. construction market conditions, political climate, etc.)

This chapter has emphasised the fact that every project's circumstances and contract strategy are unique and that a contract strategy's impact on a project is dependent on the project's circumstances. However, only the expert systems directly account for the dependence between a contract strategy's attributes and a project's circumstances.

Furthermore, all of the existing contract strategy selection models could be accused of reducing the 'project circumstances' type criteria to an insufficient number and also to an imprecise level of detail.

The majority of the models restricted this type of criteria to a combination of project size, complexity and specification completeness at tender. Like the common 'project procedure' type criteria, these few 'project circumstances' criteria are regularly used to differentiate between contract strategy types in the literature (section 2.2.4).

Some of the expert systems facilitated a more detailed account of a project's circumstances. For example, Moshini (1993) addressed project location, type of client and legal requirements. Meanwhile, Sodipo's (1987) expert system prompts the user to consider:

- level of definition of project scope and quantity of work;
- a contractor's ability to make an accurate prediction of productivity; and
- major risks (i.e. their likelihood of occurrence and consequential effects).

Contract strategy selection is a complex decision problem, fundamentally because every project's circumstances and contract strategy are unique (section 2.2.4). The models described in section 2.4 have been developed to aid the selection process. However, the models impinge, to different extents, upon the decision-maker's freedom to select the most appropriate contract strategy. Given the nature of contract strategies and the process involved in their selection (sections 2.1 and 2.2), the flexibility of a contract strategy decision-aid is perceived to be a crucial property.

2.5.2 Insufficient model flexibility

All of the graphical aid models and expert systems contain their own pre-formatted knowledge which represents experts' evaluation of a particular set of contract strategy types. In expert systems the pre-formatted knowledge dictates not only the decision options, but the decision mechanism that ascertains the appropriateness of each available option from the user's responses to the decision criteria. In addition, the specific set of decision criteria within all of the models, including the multi-attribute analysis type, can also be considered to be pre-formatted knowledge.

From the model types described in section 2.4, only the expert systems conventionally classify as knowledge-based systems. Nonetheless, the other model types clearly service some of the following utilities common to knowledge-based decision support systems (Holsapple and Whinston, 1996):

- increase the efficiency of the decision process;
- structure the decision problem;
- manage knowledge;

- propose decision options; and
- supplement the decision-maker's evaluation of the options.

In contrast, Ward *et al.* (1991c) compared theoretical decision-aid models unfavourably with applied models. Theoretical models were described as those which prescribe the optimum decision option under a particular set of precisely defined conditions (i.e. a decision algorithm for a repetitive decision problem that is always treated as identical in nature), whilst applied models were classed as those that provide a more flexible means of exploring decision options. Ward *et al.* (1991c) expressed the following perceived advantages of this latter model type:

- applied models are more robust, particularly when the correctness of the assumptions underlying the equivalent theoretical models is disputable;
- applied models tend to be more cost-effective to develop if there is a practical requirement to improve a current decision and the decision problem cannot be solved using optimisation;
- applied models facilitate marginal analysis; and
- applied models offer a more transparent approach to understanding the nature of a decision problem because there is the capacity to address relevant issues even though they have not been formally modelled.

Owing to the fact that every project's circumstances and contract strategy are unique, models that contain pre-formatted knowledge present the following significant limitations:

1. the knowledge cannot be validated; and
2. the knowledge has to remain general in order to be applicable to most project circumstances.

Owing to the above limitations, pre-formatted knowledge fosters conflicting knowledge between different experts (Hamilton, 1987; Bresnan and Haslam, 1991). All the developers of the expert systems described in section 2.4.3 acknowledged this fact. Furthermore, as a result of the second limitation cited above, the models that contain pre-formatted knowledge are inflexible, in the sense that:

1. the models' contract strategy options are imprecise and limited in number; and
2. the models' decision mechanisms are unable to account for all of the relevant case specific details.

The following sub-sections describe the inflexibility imposed by the existing decision-aid models upon the decision options, decision criteria and thus decision mechanism. Section 2.5.2.2.1 makes reference to currently ongoing research into the development of a highly intricate and thus flexible knowledge-based system to assist contract strategy selection.

2.5.2.1 Model inflexibility: decision options

Section 2.1 reported that contract strategy selection presents an infinite number of decision options. However, the expert systems and graphical aid models have restricted the decision options to comparatively small sets. Obviously, each model's set of alternatives are not comprehensive, but in addition, each option is typically referred to by a broad, albeit well-known, label which is open to considerable interpretation (e.g. Traditional, Target cost, etc.).

Some models made more precise references to their decision options than others. For example, Moshini (1993) implemented a more rigorous and systematic means of classifying contract strategies (see Table 2.10). In addition, the expert system developed by Wang *et al.* (1996) restricted the evaluated contract strategies to six standard contract forms (i.e. the New Engineering Contract options). However, this latter attempt to improve knowledge precision has the effect of exacerbating the model's inflexibility (i.e. limited number of decision options).

In contrast, there is a lot more flexibility in the models that do not constrain the decision options to those for which they only contain pre-formatted knowledge (i.e. those models that employ multi-attribute analysis). These models effectively allow the user to evaluate contract strategies of their own choice. Hence the decision-maker is able to distinguish between the specific details of contract strategies.

2.5.2.2 Model inflexibility: decision mechanism and criteria

The model's deficiencies in the interpretation of contract strategy decision criteria has already been reported in section 2.5.1. The criteria, nonetheless, provide the models' structure, they supplement the decision-maker's thought process and ensure alternative decision options are evaluated consistently against the same criteria. These are essential prerequisites of decision support systems (Keen and Morton, 1978). However, owing to the complexity of contract strategy selection, an inflexible framework of specific criteria for every project may not be the optimal approach.

It may be concluded that, instead, the model's decision criteria ought to be restrained to each client's particular primary objectives (i.e. balanced price, duration and quality targets). This is because, firstly, they are the ultimate aim of the decision process, and secondly, because as decision criteria they may be the only criteria which are applicable to every project. The only model reported in section 2.4 that used the client's primary objectives as its decision criteria is the multi-attribute utility analysis developed by Ahmad and Morad (1993).

Although the multi-attribute analysis models contain fixed decision criteria, there is still flexibility for the decision-maker to refer to, and incorporate, a range of other factors which are relevant to a specific project's contract strategy decision problem. In contrast, expert systems, as a form of artificial intelligence, are designed to model humans' decision mechanisms (Jackson, 1986). Owing to the nature of contract strategy selection, it is questionable as to whether the application of expert systems to this domain is both feasible and advisable. There is no standard contract strategy decision mechanism, nor is there an infallible means of validating any such attempt at a general, standard decision mechanism. Furthermore, the perceived advantages of modelling experienced contract strategists' decision mechanisms may be flawed given the deficiencies perceived to be common to the industry's approach (section 2.3.2).

It has been widely acknowledged that artificial intelligence is most suited to decision problems that cover a well defined domain of knowledge (Turban, 1988; Brandon, 1990). Perry (1985) expressed strong doubts with regards to representing contract strategy selection as a rigid set of rules and procedures. Consequently, Perry (1985) proposed a decision methodology which outlined a general approach to contract strategy selection. Although Perry has since been involved in the development of an expert system related to contract selection (Wang *et al.*, 1996), it was emphasised that the expert system was designed primarily as a learning tool. In addition, both Perry (1995) and Ashworth (1991) have acknowledged that there is considerable scope for the industry to improve its understanding of contract strategies.

2.5.2.2.1 Potential to improve the flexibility of pre-formatted knowledge

Expert systems have been described in some sources as flexible (Buchanan and Duda, 1983; Moshini, 1993). This is because knowledge can be continually added to an expert system's existing knowledge base. Wong and So (1995) suggested that their expert system can become self-learning with the aid of neural networks.

More recently, Kumaraswamy (1997) proposed that an integrated system of artificial intelligence techniques (i.e. artificial neural networks, generic algorithms, case-based reasoning, fuzzy logic and expert systems) could optimise the intricacy of a prescribed contract strategy selection mechanism. Kumaraswamy (1997) also claimed that techniques such as the analytical hierarchy process and factor analysis, could reduce the subjectivity in discerning the impact that a contract strategy has had on a project. According to Kumaraswamy (personal communication), the results of this research are planned to be published in September 1999. Nonetheless, the preparatory work by Kumaraswamy (1997) illustrated the considerable obstacles one is faced with in the development of a highly structured knowledge-based model that aims to be applicable to most project circumstances and offer a diverse range of contract strategy options.

2.5.3 Failure to rationalise decision uncertainty

Section 2.2 established that:

- the impact that a contract strategy will have on a project is uncertain; and

- a forecast of a contract strategy's impact on a project has to based upon imperfect, and thus uncertain and subjective, information.

It may be inferred that all of the models described in section 2.4 are likely to reduce some of the uncertainty because each model imposes a structure to the decision process (Chapman and Ward, 1997). However, some of the models which embodied numerical analysis (i.e. those other than graphical aids) have not addressed the uncertainty directly or with notable rigour.

The basic multi-attribute value analysis models simply prompted the decision-maker to assign a single value to represent the perceived performance or suitability of a contract strategy with respect to each criterion. The basic multi-attribute utility analysis developed by Ahmad and Morad (1993) incorporated the most basic probability trees (i.e. two alternative outcomes) to enable the decision-maker to account for the potential impacts that a pricing mechanism type could have on a project's price, duration and quality outcome.

The expert systems used probability and/or fuzzy set theory. However, it may be argued that contract strategy selection expert systems introduce an additional level of uncertainty to the decision problem. Owing to their use of pre-formatted knowledge, certain aspects of the expert systems' decision-making process are open to linguistic interpretation. These aspects include a user's inputs, the evaluated contract strategies and the models' decision rules. This source of uncertainty is, in theory, avoided if an individual relies upon his/her own knowledge, rather than that of others.

2.6 Conclusions and research proposals

Sections 2.1 and 2.2 described the nature of the contract strategy decision problem. In the light of this information together with reported criticisms of the industry's contract strategy selection practice, several deficiencies inherent in the industry's typical approach to the decision problem were identified. These deficiencies include:

- limited appreciation of the decision options;
- failure to set clear, realistic and balanced price, duration and quality targets;
- failure to wholly rationalise decisions in terms of the client's primary objectives;
- unstructured and imprecise decision mechanisms;
- the decision process is not explicit or transparent; and
- failure to account for the uncertainty inherent in contract strategy selection.

Section 2.3.2 provided justification for the assumption that these deficiencies were expected to give rise to:

1. a reduction in the likelihood that the most appropriate contract strategy will be selected for a project; and
2. a restriction on the capacity to appreciate the actual impact that a selected contract strategy has upon a project.

As a result a new approach to contract strategy evaluation was proposed with the aim to eliminate the deficiencies perceived to exist in the industry's typical evaluation process. The principal facets of the new approach can be referred to simply as:

- flexible; and
- quantitative.

The subsequent sections describe these two facets of the approach and their capacity to resolve the above-listed deficiencies of the industry's approach to contract strategy evaluation. Reference is also made to the literature that supports the feasibility of the new approach.

2.6.1 The capacity of a flexible approach to eliminate deficiencies in the industry's typical approach

The existing contract strategy selection models imposed a structure upon the decision process and made the process explicit. However, it is perceived that the models incorporate many of the deficiencies considered to be inherent in the industry's approach to the decision problem.

Section 2.5.2 listed advantages and disadvantages associated with decision-aids that contain pre-formatted data. Owing to the nature of contract strategies and their selection process, it was expounded that the models' pre-formatted knowledge constituted a generalisation, and thereby an oversimplification, of the decision problem. It was therefore concluded that an experienced and competent contract strategist would be inhibited by, and would be unlikely to gain insights from, the models described in section 2.4. Instead it appeared more appropriate to give the decision-maker the flexibility to:

- evaluate whichever contract strategies the decision-maker perceives may be the most appropriate;
- define each contract strategy in terms of the most appropriate level and type of detail; and
- evaluate each contract strategy in terms of the most relevant issues.

The first and second of these flexible procedures serve to resolve the first perceived deficiency of the industry's typical approach listed in the preceding section; limited appreciation of the decision options. Meanwhile, the third flexible procedure aims to facilitate a precise decision process which is specific to each contract strategy decision problem (thus corresponding to the deficiency listed third in the preceding section).

It is appreciated that a decision-maker with total flexibility to direct the evaluation process at his/her discretion may encourage, not eliminate, the other listed deficiencies. However, the following section suggests how the flexible approach may become disciplined if contract strategy options are evaluated quantitatively.

2.6.2 Quantitative evaluation of contract strategies

Essentially it is proposed that, within the new approach, a contract strategy's perceived appropriateness for a specific project is to be reflected in estimates of the project's price and duration assuming that the contract strategy is implemented. Hence the new approach demands that prospective contract strategy options for a given project are to be evaluated expressly against the client's primary price and duration objectives.

Since this chapter has emphasised the importance of all three of the client's primary objectives (i.e. balanced price, duration and quality targets) it may appear inconsistent to suddenly demote the quality objective. The following sections justify the focus upon price and duration with section 2.6.2.1explaining that a project's quality requirements could be expressed in terms of the price and duration objectives.

2.6.2.1 Justification for demoting quality to a secondary objective to price and duration

With regards to the client's primary objectives, a project's price and duration targets can be expressed in distinct units of cost and time, respectively. However, measures of quality are open to subjective interpretation because there are no express units of quality. As a result, a client organisation's quality target for its project is very difficult to:

1. specify (section 2.2.3 made reference to Garvin (1988) who identified eight different dimensions of quality); and
2. assess whether or not it has been achieved at project completion (Curtis *et al.*, 1991).

Rwelamila and Hall (1995) noted that the majority of literature on the subject of project management systems focused upon cost and time factors whilst quality has been largely ignored. There is the opinion that a project's quality outcome is exposed to less risk than a project's price and duration. Wright (1997) implored project managers to increase their efforts to enable projects to achieve the client's price and time targets, whilst he reduced the importance of the quality objective by claiming that projects are normally completed, effectively, to specification. A similar view was expressed by Turner (1997) who regarded project quality as dependent upon the quality of the design concept, materials and workmanship. Therefore Turner (1997) claimed that a quality target should be attained providing:

1. the contract specification is sufficiently detailed; and
2. mechanisms and procedures of inspection are adequate.

Section 2.2.3 reported that a client's primary objectives are interdependent. Therefore it may be concluded that a client organisation's quality target could be specified in terms of the amount of money and time invested, or not invested, in courses of action which may influence project quality (e.g. establish a client's specification, project monitoring resources, tender competition, etc.). This is in addition to the qualitative specification of quality within a project brief.

2.6.2.2 The capacity of the quantitative approach to eliminate deficiencies in the industry's typical approach

Section 2.6.1 indicated which deficiencies of the industry's contract strategy selection practice could be resolved by a flexible approach. It is perceived that a quantitative evaluation process could eliminate the other deficiencies (listed at the beginning of section 2.6). This is because the quantitative approach:

- <u>provides a structure to the decision process</u>
  The result of the quantitative evaluation process for a specific contract strategy is a forecast of the relevant project's price and duration. Rather than undertaking a holistic estimate of price and duration it is possible to obtain more accurate estimates by disaggregating a project's price and duration into constituent cost and time elements (e.g. design cost, tender process costs, construction duration). Therefore a structure to the decision process is imposed by establishing a set of cost and time elements against which contract strategies can be evaluated. This will also ensure that a set of alternative contract strategy options are evaluated consistently against the same criteria.
- <u>does not impinge upon the decision-maker's flexibility</u>
  The decision-maker has the capacity to evaluate any contract strategy with respect to the most relevant issues. Cost and time are applicable decision criteria in all projects.
- <u>facilitates setting clear, realistic and balanced price and duration targets</u>
  Price and duration targets can be expressed in precise, unambiguous units of cost and time, respectively. Section 2.6.2.1 suggested that a quality target may also be specified in units of cost and time. Lifson and Shaifer (1982) supported quantitative specification of a client's objectives and requirements, wherever possible.
  In order to set realistic and balanced price and duration targets Curtis *et al.* (1991) insisted that it was necessary to "break a project down into component parts and

build up project goals from plans associated with components". This process can certainly be implemented under the quantitative approach. It has already been established that the decision problem can be disaggregated into a particular project's constituent cost and time elements in which the elements can equate to activities. The flexibility of the approach enables the decision-maker to plan a project at any level of detail and address any relevant issue. Furthermore, owing to the quantitative nature of the elemental evaluations and plans, it is possible to combine them to produce all-encompassing, explicit results in quantitative form.

- <u>disciplines the decision-maker to wholly rationalise decisions in terms of the client's primary price and duration objectives</u>
  The quantitative approach demands that all subjective assumptions used to differentiate between contract strategies make direct reference to a project's price and duration outcome. Hence those assumptions which are often instinctively interpreted as a favourable or unfavourable feature of a contract strategy (e.g. tender competition and risk transfer enabling value for money) have to be evaluated and rationalised expressly in terms of their expectant impact upon the client's price and duration objectives.

- <u>disciplines the decision-maker to make all decision assumptions and reasoning explicit</u>

  Quantitative analysis is more explicit and definitive than qualitative analysis (Chapman and Ward, 1997). Lifson and Shaifer (1982) said that "consistency, as well as communication and understanding, implies that information should be stated quantitatively". Furthermore Chapman (1992) acknowledged the significant assistance provided by graphical presentations of processed information to decision-making.

- <u>facilitates an explicit account, and analysis, of the uncertainty inherent in contract strategy selection</u>
  Quantitative estimates which reflect the decision-maker's subjective assumptions about a contract strategy can be represented by probability distributions. The distribution estimates also reflect the uncertainty inherent in the subjective assumptions. By combining the estimates it is possible to obtain a quantitative overview of each contract strategy decision problem and therefore use the variety of techniques available to interpret quantitative data (e.g. mean, conditional mean, variance, etc.) and to analyse the robustness of the whole quantitative process (i.e. sensitivity analysis).

2.6.2.3 Feasibility of the quantitative approach

Section 2.2.4.1 reported three cases (Pain and Bennett, 1988; Chisnall, 1991; Pedwell *et al.*, 1996) where the suspected impact of contract strategies upon particular projects were estimated quantitatively in terms of the projects' cost and time performances. Furthermore, in these cases, the differences between a project's expected cost and time outcomes under different contract strategies were substantial enough to conclude that this approach was a valid means of distinguishing between available options in a particular project.

Section 2.4.2 described a contract strategy decision-aid that modelled a very basic quantitative approach to contract strategy evaluation. The multi-attribute analysis developed by Ahmad and Morad (1993) required the decision-maker to estimate two alternative price and duration outcomes of the project and their corresponding probabilities for each contract strategy evaluated.

It may be argued that the considerable uncertainty presented by contract strategy selection renders the quantitative approach implausible. It should also be noted that subjective estimates are highly susceptible to judgmental biases (section 2.3.1). Hertz and Thomas (1984) and Goodwin and Wright (1998) provided detailed explanations of the biases prevalent within subjective estimates, particularly probabilistic estimates. Vose (1996) described a variety of other sources of estimating inaccuracies. However, Chapman and Ward (1997) proclaimed "given that individuals are guided by their perceptions of uncertainty whether or not quantification is attempted, it makes sense to articulate these perceptions so that uncertainty can be dealt with as effectively as possible".

O'Brien (1965) reported that, the then recently developed, Critical Path Method was greeted with some derision by professionals experienced in construction management. This analysis technique has since become one of the most widely used planning tools. Similarly, the concept of project risk analysis and management has been formalised over the past two decades and although it may not be implemented throughout the industry (Akintoye and MacLeod, 1997), the sheer volume of literature on the subject demonstrates that both its use and popularity has increased during this period. Therefore, owing to the acclaimed importance of contract strategy selection and deficiencies in the industry's current practice, there certainly appears to be scope and reason to propose an analytical approach to contract strategy selection, alternative to those already developed.

3. The development of a prototype model

In order to clarify the stages of model development section 3.1 provides a summary of the complete research programme. Section 3.2 describes the development of a conceptual knowledge-based model, whilst section 3.3 outlines the conceptual basis for, and implementation of, the quantitative approach.

3.1 A summary of the research programme

Chapter 6 describes a series of sample analyses using a model that calculates a project's cost and time performance from estimates that reflect the potential impact of a contract strategy upon the project in question. Several phases of research led to the development of the model in its final form.

Initially a knowledge-based model was developed. This model is described in section 3.2. The impetus for the design of a knowledge-based model was the fact that existing literature focused heavily on the relative appropriateness of different contract strategies in different circumstances (see section 2.2.4).

The attempt at a knowledge-based model was a useful experience. It reinforced the conclusions of chapter 2; a quantitative approach offers significant advantages relative to a model that contains pre-formatted knowledge (see section 2.6). It was decided, therefore, to construct a probabilistic model which would allow a user to input quantified estimates that reflect the potential impact of contract strategies upon a project and which would output quantified estimates of the project's cost and time performance. The process and concepts employed in the development of this model are described in section 3.3.

The principles of the model described in section 3.3, which is here described as the "prototype model", were reviewed in a survey of several construction professionals. This empirical study is the subject of chapter 4.

The results of the empirical study, together with an appreciation of design compromises with the prototype model, led to the design of an upgraded model version. The 'refined model' is described in chapter 5. The refined model was used to carry out the analyses presented in chapter 6.

3.2 A knowledge-based model

Initially the aim of the research was to devise a contract strategy decision-aid that contained pre-formatted knowledge. This was driven by the perception that the pre-formatted knowledge in existing decision-aids was defective on two main levels:

1. The relationships between the models' decision criteria and the client's primary objectives relied upon theories that could be described as very general, preconceived and untested (e.g. in some existing models it is inferred that competitive tendering unconditionally induces a low project price – see section 2.5.1)

2. Contract strategy alternatives are restricted to a limited number of pre-defined options, and each is imprecisely defined.

It was decided to investigate whether it was possible to design a knowledge-based model that:

- evaluated a wider range of more precisely-defined contract strategies;
- took a greater account of a project's specific circumstances; and
- measured the suitability of each evaluated contract strategy in terms of probable effects upon the cost and time performance of projects.

Figure 3.1 shows part of a model designed to address these requirements. The particular section of the model featured in Figure 3.1 is designed to aid a decision-maker ascertain the pricing mechanism type most likely to minimise a project's construction cost. Other sections addressed sub-objectives additional to 'minimise construction cost' (e.g. fix construction costs, minimise construction time, maximise construction performance). It was envisaged that a similar overall approach could be applied to determine the most appropriate organisational structure and tender process.

It has already been established that the section of the knowledge-based model featured in Figure 3.1 deals with the sub-objective 'minimise construction cost' (Column 1). It is considered that there are certain 'pricing mechanism resources' (Column3) which govern the extent to which the sub-objective is achieved. The relative contributions of each 'pricing mechanism resource' is reflected in the weighting factors (Column 2). For example, Figure 3.1 shows that profit incentive is regarded as having a greater influence (weight 0.3) than project scope definition (weight 0.1).

The 'property options' (Column 4) within each 'pricing mechanism resource' (Column 3) were intended to differentiate between pricing mechanism types (e.g. for the resource 'scope definition', a unit price type pricing mechanism might be characterised by the third property option 'well-defined scope' whilst, in contrast, a cost reimbursable type pricing mechanism might be characterised by the first property option 'broadly-outlined scope'). For each pricing mechanism resource, a pricing mechanism type was assigned an 'ability score' (Column 5) that corresponded to the property option associated with the pricing mechanism type (the maximum score value was 10). Each ability score was then multiplied by a 'suitability factor' (Column 6). The suitability factor aimed to reflect the capacity of the property option to achieve the 'sub-objective' (Column 1) given that the project was either a low, medium or high risk project. The sizing of a project risk was to be determined from a separate scoring system in which the decision criteria related to project circumstances (e.g. project type, size, status, particular risks, the client's cost and time priorities, capabilities of contracting parties, etc.). The overall measure of a pricing mechanism type's capacity to minimise a given project's construction cost was equal to the sum of the products of the pricing mechanism type's ability score, suitability factor and weighting factor along each pricing mechanism resource branch featured in Figure 3.1.

For example, consider the comparison of a 'unit price' and a 'cost plus fixed fee' type pricing mechanism for a 'low' risk project. Table 3.1 shows which property options (see Column 4 in Figure 3.1) correspond to the unit price mechanism and the subsequent quantitative values that are used to calculate a measure of the pricing mechanism type's appropriateness in a low risk project. Table 3.2 presents similar details for the cost plus fixed fee mechanism.

Pricing mechanism resource	**property option**	**ability score**	**suitability factor**	**resource weighting factor**	**product**
Scope definition	3	9	10	0.1	9
Pre-award quantification	4	9	3	0.2	5.4
Sum stability	2	7	6	0.2	8.4
Cost controls	3	9	2	0.2	3.6
Profit incentive	4	8	6	0.3	14.4
				TOTAL SCORE	**40.8**

Table 3.1 Application of the knowledge-based model to measure the appropriateness of a unit price type pricing mechanism for a low risk project

Pricing mechanism resource	**property option**	**ability score**	**suitability factor**	**resource weighting factor**	**product**
Scope definition	1	3	4	0.1	1.2
Pre-award quantification	2	5	6	0.2	6
Sum stability	3	6	2	0.2	2.4
Cost controls	2	5	7	0.2	7
Profit incentive	2	3	7	0.3	6.3
				TOTAL SCORE	**22.9**

Table 3.2 Application of the knowledge-based model to measure the appropriateness of a cost plus fixed fee type pricing mechanism for a low risk project

Comparison of the total scores calculated in Tables 3.1 and 3.2 indicate that, in a low risk project, a unit price type pricing mechanism, relative to a cost plus fixed fee mechanism, is a better option for minimising construction cost.

Although the approach had some advantages over existing decision-aids, it gradually became apparent that this approach to the contract strategy decision problem was beset with problems. Fundamentally, it was perceived that a generalisation of the decision problem would inevitably be an over-simplification, regardless of the detail in the pre-formatted knowledge (see section 2.5.2). As a result, it was expected that an experienced contract strategist would gain little benefit from a model that contains generally-applicable knowledge about contract strategy selection.

Seymour *et al.* (1996) criticised construction management researchers for their common failure to acknowledge and account for the contextual nature of pre-formatted knowledge embodied in generic models. Seymour *et al.* claimed that the knowledge is likely to 're-contextualised' and thus both its validity and utility are questionable.

Clearly validity is a crucial requirement for a model that contains pre-formatted knowledge. However, there is no infallible means of testing the validity or utility of a contract strategy decision-aid model. Section 2.2.4 reported that it is not possible to ascertain the precise impact that a contract strategy has upon a project. Therefore any model tests would be inherently subjective and considerable testing would be required before a model could be claimed to be valid.

The realisations which developed from the initial research direction led to a change in the approach to the subject. It was concluded that the development of a model that contained pre-formatted knowledge, of the type described earlier in this section, was unlikely to lead to significant improvements in contract strategy selection from an academic or an industrial perspective.

It was theorised that the mental knowledge-base of each individual contract strategist possessed the greatest potential to become the most efficient and effective contract strategy decision-aid. Therefore the research set out to investigate how improvements to an individual's knowledge about contract strategy selection could be achieved and also how the individual could self-perpetuate these improvements. The concept of the quantitative approach to contract strategy evaluation developed thereafter.

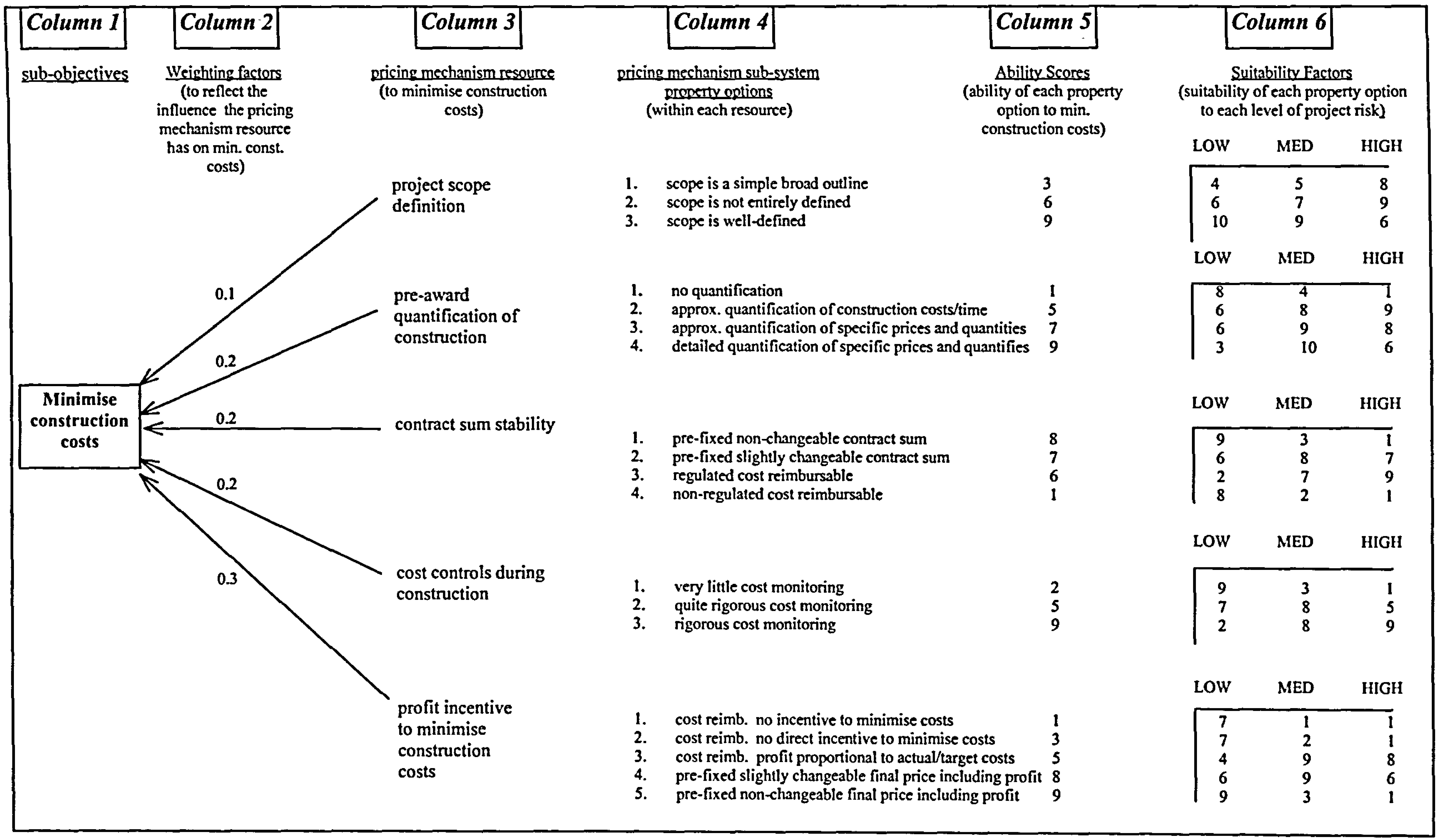


Figure 3.1 A knowledge-based model designed to ascertain the pricing mechanism type most likely to minimise construction cost

3.3 The prototype quantitative model

Section 2.6.2 introduced the quantitative approach as a process in which a prospective contract strategy's appropriateness for a specific project is to be reflected in estimates of the project's price and duration, assuming that the contract strategy is implemented. Therefore the quantitative approach is essentially a methodology as opposed to a directly applicable tool. As such, the model had to be designed as a flexible framework which may be applied and interpreted by the decision-maker to facilitate quantitative evaluation of contract strategies in specific scenarios.

During the design of the model, decisions had to be made which constrained the model's flexibility. This is because the short-term priority was perceived to be the production of a model that enabled the fundamental principles of the quantitative approach to be tested. Although the model limitations are identified at the end of this chapter, they are explained in more detail in chapter 5, which also describes the refinements subsequently made to the model.

The remainder of this chapter describes the first version of the quantitative model (i.e. the prototype model) as well as the process involved in its development. Example demonstrations of the model are provided. There is also guidance as to how and when to use the model.

3.3.1 The outline components of the prototype model

Figure 3.2 illustrates the basic concepts of the model:

1. probabilistic estimates of a project's constituent cost and time elements are inputted into the model;
2. the model performs a variety of computations; and
3. the model outputs probabilistic estimates of the project's price and duration.

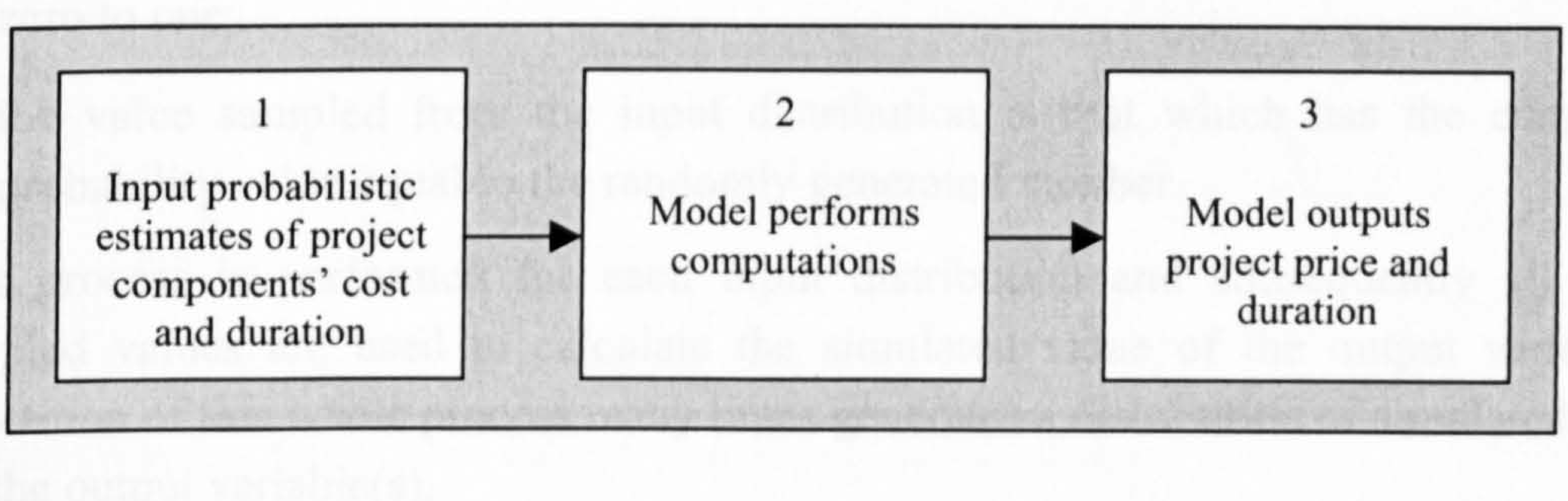


Figure 3.2 The basic process involved in the application of the prototype model

The quantitative approach is an analysis intended to estimate a project's cost and time performance assuming that the project is procured using a particular contract strategy.

Therefore it was recognised that a simulation-based analysis was required. Furthermore, in order to address the uncertainty surrounding contract strategy selection, the simulation had to be stochastic.

A project may be considered to consist of a number of activities or elements. It was appreciated that the elemental project breakdown could have consisted of a simple list of consecutively-running activities or the more complex alternative of a precedence network of activities. The latter option was considered more appropriate because it provided the degree of realism and sophistication that enabled the outputs to be relevant to real project situations.

Owing to these analytical prerequisites and the number of components to be simulated, it was decided to use Monte Carlo simulation in the model. As a result of this decision, a variety of subsidiary matters required consideration, including:

- details of the simulation technique; and
- type of probability distribution used for model input estimates.

Each of these is discussed in the sub-sections which follow.

3.3.1.1 Description of Monte Carlo simulation

Bernie and Yates (1991) described Monte Carlo simulation as the appropriate technique to use where "the final outcome to a decision problem depends on the outcomes of a number of different events (sub-problems) and in the manner in which they combine". The technique involves randomly sampling values from the input probability distributions before they are suitably combined to give a value for the output variable(s) (Simon *et al.*, 1997). The sampling method associated with Monte Carlo simulation generally adhere to the following procedure, regardless of the input distribution type (Vose, 1996):

- a random number is generated from a uniform distribution of values ranging from zero to one;
- the value sampled from the input distribution is that which has the cumulative probability value equal to the randomly generated number.

This process is performed for each input distribution and subsequently all of the sampled values are used to calculate the simulated value of the output variable(s). Repetition of this whole process many times generates a distribution of simulated values for the output variable(s).

With respect to the quantitative approach to contract strategy evaluation, application of Monte Carlo simulation aims to calculate a probability distribution of project price and duration for each contract strategy evaluated. Therefore the input variables are the constituent cost and time elements of a project's price and duration which a contract strategy is expected to have some impact upon. The assumed impact of a contract strategy is to be reflected in each element's probability distribution estimate. The distribution estimates are subsequently combined using Monte Carlo simulation. The following section reports and justifies the use of triangular probability distributions to model the potential value of the input variables.

3.3.1.2 The use of triangular probability distribution functions

A decision was made to model the values of the uncertain input variables using triangular probability distribution functions (Figure 3.3a). This distribution type has previously been used for construction cost and time estimates (Raftery, 1991; Newton, 1992; Williams, 1992). However, it has been claimed that triangular probability distributions do not provide realistic representations of construction cost data (Flanagan and Stevens, 1990; Chau, 1995a; Chau, 1995b; Wall, 1997). According to Chau (1995a and 1995b) they inherently induce over-estimation of risk exposure when the maximum value of a variable is estimated at its maximum extreme value. The broken line in Figure 3.3b is considered to be a more realistic representation of the possible cost outcome beyond the most likely value.

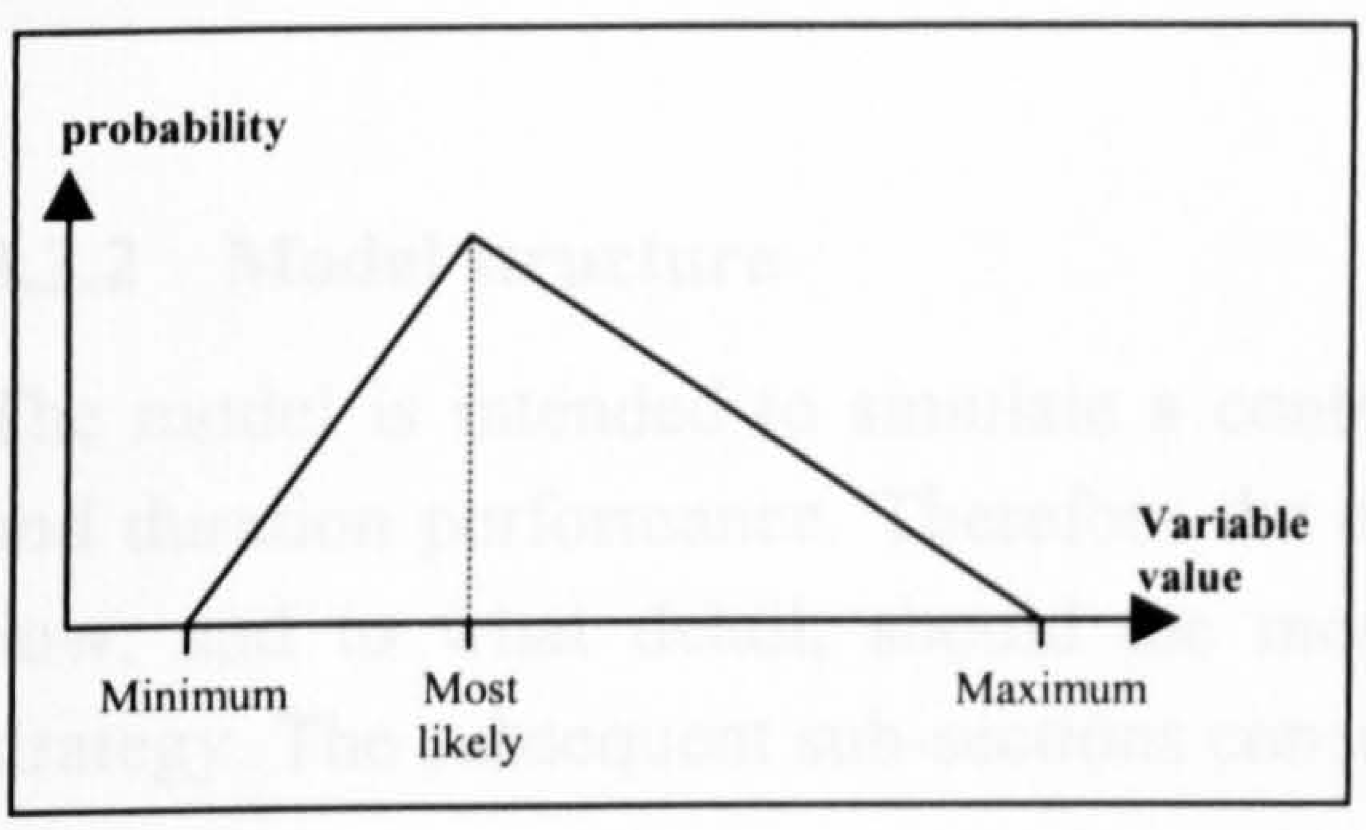


Figure 3.3a Triangular probability distribution

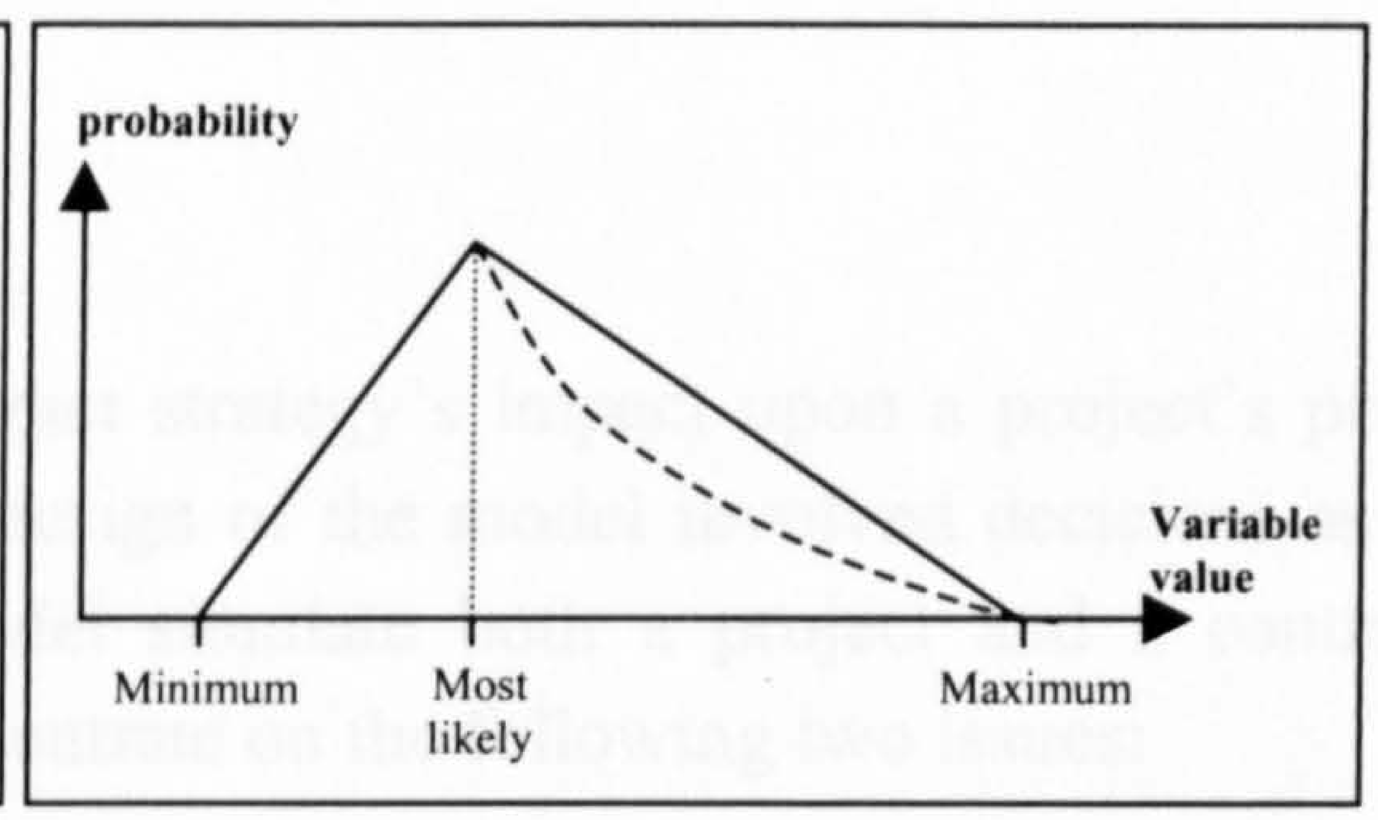


Figure 3.3b A more realistic representation of construction cost uncertainty (Chau, 1995b)

Consequently the probability distributions which have been proposed as more accurate models of construction cost data include:

- Beta distribution (Flanagan and Stevens, 1990);
- Lognormal distribution (Tauron and Wiser, 1992); and
- Log-triangular distribution (Chau, 1995b).

These three distribution types are derived mathematically (i.e. parametric distributions) whereas the triangular probability distribution function is defined by the required shape which in turn dictates the distribution's mathematics (i.e. non-parametric distribution).

Owing to their non-parametric property, triangular distributions have been described as particularly useful for subjective estimates as opposed to estimates based upon historical, objective data (Williams, 1992; Vose, 1996; Chapman and Ward, 1997). Vose (1996) reported that non-parametric distributions (i.e. Uniform, General, Triangle, Cumulative and Discrete) are more reliable and flexible than parametric distributions (e.g. Normal, Beta, Lognormal, etc.) because:

- parametric distributions are more difficult to review later because the parameters which define the distribution have no intuitive appeal;
- models that utilise parametric distributions are less transparent and therefore it is more difficult to assure the decision-maker of the model's validity;
- parametric distributions are difficult to revise when new relevant information becomes available because the distribution's parameters are not directly related to the real data; and
- parametric distributions are difficult to refine because the effects of changes in the distribution's parameters are difficult to understand.

As a result, triangular distributions appeared to be a suitable means of representing the uncertain variables in the model. It also appeared appropriate to investigate industrialists' reactions to the distribution type during the empirical research.

3.3.2 Model structure

The model is intended to simulate a contract strategy's impact upon a project's price and duration performance. Therefore the design of the model involved decisions as to how, and to what detail, should the model simulate both a project and a contract strategy. The subsequent sub-sections concentrate on the following two issues:

- which particular aspects of a project's performance and contract strategies are simulated by the model; and
- numerical relationships between the simulated elements and the measure of a project's performance which reflects the impact of a contract strategy.

One should also note that a decision was made to code the model within Microsoft Excel. The decision was based upon the following realisations about Excel:

- readily accessible;
- very useful in-built analysis appropriate for the particular purposes of the model;
- straightforward user-interface; and
- availability of relevant expertise.

3.3.2.1 Simulation of project performance

A project's price and duration can be simulated by suitably building up the constituent cost and time elements. The identification of the time elements simply involves a breakdown of a project into a series of activities. Although the cost of the project activities contributes to the attainment of a project's price, the price that a client pays for production activities (i.e. design and construction) is also dependent upon the type of contract strategy used to procure the project. Therefore the simulated price elements do not solely comprise the project activities, but also include parameters that are dictated by the contract strategy type or, more specifically, the pricing mechanism type. These parameters and the calculation process required to determine a project's price are described in detail in section 3.3.2.3.1.

3.3.2.1.1 Production activities

The two primary production activities in any construction project are design and construction. For simplicity with respect to the model design, it was decided to impose some restrictions on the breakdown structure of project production. The design activity was fixed as a single activity and the user was able to divide construction into a maximum of four activities. All of the activities chosen to represent project production are referred to as individual cost and time elements.

3.3.2.1.2 Tender process activity

According to Corrie (1991) there are generally four stages to tendering:

1. selection of tenderers;
2. invitations to bid;
3. tender preparation and delivery; and
4. appraisal of tenders, negotiation and decision.

It was intended to include the costs incurred by the client during these stages in the determination of a project's price as well as to include the duration of the activity's procedures within the calculation of project duration. The user of the model is simply prompted to estimate the cost (incurred by the client) and the duration of the overall tender process. Therefore the user can use his/her discretion to include whichever items are appropriate given the project circumstances and the type of tender process under evaluation. Like each production activity, the tender activity is referred to as a cost and time element. Section 3.3.2.2 explains that the model is designed to simulate just one tender activity within each contract strategy.

3.3.2.1.3 Transaction costs

This section concerns a cost element as opposed to a project activity. A description of the cost element follows together with justification for its inclusion in the simulation of a project's performance.

Transaction costs within the construction industry and their relevance to contractual arrangements has been highlighted by Rene and Levitt (1984) and Winch (1989). Transaction costs essentially refer to administrative type costs which are incurred when one party employs another party to perform a service.

Winch (1989) suggested that the transaction costs incurred on construction projects can be significant because construction projects are executed by a temporary coalition of independent organisations. As a result, the relationships between the different organisations are market-orientated and incite opportunistic behaviour, particularly given the considerable uncertainty presented by construction projects. In other words, the level of transaction costs is largely effected by a contract strategy's type of organisational structure, since this governs the number and type of contractual interfaces.

Winch (1989) included the following general items under the title of transaction costs:

- preparation of bills of quantities and other contract documents;
- estimating effort by subcontractors;
- dispute resolution; and
- contract management by designers, quantity surveyors and contractors to deflect opportunistic behaviour of the other parties.

Rene and Levitt (1984) recognised that all costs of this type, irrespective of whichever project party directly expended them, will eventually be borne by the client.

The model prompts the user to estimate a distribution of transaction costs, which the client may incur, for each contract strategy that is evaluated. Since there is no definitive list of items within the transaction costs element, the user is given the flexibility to include items which appear most appropriate in a given application of the analysis. It is important, however, to avoid duplication of cost items within the series of elemental estimates.

3.3.2.2 Simulation of contract strategies

Owing to the complex nature of contract strategies (section 2.1), it was decided to simulate only certain general features that are common to most contract strategies. Primarily, these features included work packaging, together with the type of tender process and pricing mechanism implemented within the contract between the client and the contractor that is assigned responsibility for the construction.

It was recognised that it would be difficult to develop a model which provided a general framework with which any contract strategy could be defined in terms of the previously identified features. Therefore it was decided to make a compromise in this first version of the model.

The development of the prototype model coincided with the development of the empirical research strategy. Section 4.3.3 describes the design of a questionnaire that requested respondents to evaluate three specific contract strategy types. It appeared appropriate to define each of the three contract strategies within the questionnaire in terms of its work packaging, together with its type of tender process and pricing mechanism implemented within the contract between the client and the contractor that is assigned responsibility for the construction. Therefore it was decided to restrict the contract strategy options within the prototype model to the same three alternatives presented in the questionnaires. The contract strategies were defined as follows:

1. **Traditional:** a team of design consultants complete the design and administer the project. The design is complete before the construction is let to a general contractor using a negotiated tender process. The client's detailed bill of quantities is used to negotiate a Guaranteed Maximum Price (any cost savings are shared equally) and it also provides a basis for re-measurement of the price.

2. **Design-Build:** the remainder of the design and the entire construction work is let as a single package using a competitive one-stage tender process. The package is let on the basis of a fixed lump sum price.

3. **Management Contract:** a management contractor is appointed during the conceptual design stage following a pre-qualification process and negotiation of the management contractor's fees. The pre-construction fee is a lump sum, while the fee for services during construction is based on a target cost arrangement where the management contractor receives a percentage value of the construction cost, but any cost savings or overruns relative to a negotiated target cost are shared equally between the client and management contractor. The management contractor divides the construction into work packages and each package is tendered competitively on the basis of a cost plus percentage fee payment mechanism. The management contractor administers the tender process for each work package.

It is assumed that these alternatives limit the number of contracts between the client and contracting parties to those displayed in Table 3.3. Table 2.1 presented the common arrangement associated with each of these organisational structure labels. The contracts correspond to the simulated work packaging enforced within each contract strategy.

	Tasks allocated by the contracts within each contract strategy option		
Contract Strategy	**contract 1**	**contract 2**	**contract 3**
Traditional	construction	design	
Design-Build	design and construction		
Management Contract	construction	design	management services

Table 3.3 A breakdown of the prime contracts held by the client within each modelled contract strategy option

The contracted party responsible for, at least, project construction (Contract 1 in Table 3.3) is hereafter referred to as the 'principal contractor'. Table 3.4 shows the common title used to refer to the principal contractor in each of the three contract strategy options. An assumption was made to treat the series of works contractors under the Management Contract arrangement as one single principal contractor.

Contract Strategy	**Common title of principal contractor**
Traditional	General contractor
Design-Build	Design-Build contractor
Management Contract	Works contractors

Table 3.4 The principal contractors within each modelled contract strategy option

The description of the Management Contract option includes reference to the tendering procedure and pricing mechanism associated with the management services contract (Contract 3 in Table 3.3). However, other than with the Management Contract option, the descriptions of the three alternative contract strategies define the type of tender process and pricing mechanism implemented solely within the contract between the client and the principal contractor. These descriptions reflect the decision made to focus the model predominantly upon this contract. The decision was considered justifiable because construction typically accounts for the greatest proportion of a project's price and its inherent uncertainty. The model's focus upon this contract manifests as a more rigorous analysis to calculate the contract price. This is demonstrated in section 3.3.2.3.1.1.

Beforehand, however, it is important to acknowledge that the user is obliged to interpret and appreciate the specific details of each evaluated contract strategy option and reflect these in the estimates. Therefore, although the model restricts the simulated contract strategies to three alternatives, the user must recognise that each alternative presents an array of options. For example, a set of alternative Traditional-Negotiated-Guaranteed Maximum Price options could differ with respect to:

- allocation of particular risks;
- delegation of responsibility to the client's principal advisor;
- use of specialist subcontractors; or
- quality control measures.

The model facilitates this type of marginal analysis. Iterative analyses are perceived as very useful given the complexity and uncertainty presented by contract strategy selection.

3.3.2.3 Numerical analysis

The following sections describe the mathematical relationships between the model's input and output variables. The input variables are the estimated cost and time elements, while the output variables equate to a project's price and duration performance for a specified contract strategy.

3.3.2.3.1 Project Price

Project price is obtained by summing the price, paid by the client, for each of the client's prime contracts together with the tender process cost and transaction costs. It was established in section 3.3.2.2 that each modelled contract strategy option comprises a different set of prime contracts. As a result, the project price calculation is different for each of the three contract strategy options. A further difference in the calculation is caused by the contract strategies' different pricing mechanism types.

The subsequent sub-sections describe the calculation required to obtain the price of each type of contract identified in Table 3.3.

3.3.2.3.1.1 Calculation of the price of the principal contractor's contract

The analysis used to calculate the price of the contract between the client and principal contractor is governed by the type of pricing mechanism implemented within the contract. This is because each pricing mechanism type presents a different method of establishing the price of a contract (see Table 2.2 in section 2.1.2). Essentially most pricing mechanism types can be represented by a mathematical formula that determines the contract price from the actual contract costs and/or the values of the tender bid parameters particular to the pricing mechanism type.

The tender bid parameters are so called because their values are typically established at a contract's tender stage. Table 3.5 lists the tender bid parameters relevant to the pricing mechanisms employed in the contract between the client and principal contractor in each of the three modelled contract strategy options. Table 3.5 also presents the mathematical relationship which relates these parameters and the actual contract costs with the contract price. The contract price formulae derive from Gilbreath (1983), Hendrickson and Au (1989) and Chapman and Ward (1994).

Contract Strategy	Pricing mechanism	Tender bid parameters	Contract price formula
Traditional	Guaranteed Maximum Price	• Guaranteed maximum price (G) • Target contract cost (T) • Target fee (fixed) (F) • Sharing rate (b)	If $C + F + b(T - C) < G$ Then General contractor's contract price = $C + F + b(T - C)$ Else General contractor's contract price = G
Design-Build	Fixed lump sum	Fixed sum (V)	Design-Build contractor's contract price = V
Management Contract	Cost plus percentage fee	Percentage fee level (f)	Works contractors' contract price = $C(1 + f)$

Notes:

C = Actual contract costs to the principal contractor

The sharing rate (b) is treated as a deterministic variable because it is assumed that this value is dictated by the client. In the context of the above formulae, the sharing rate is interpreted to mean the proportion of savings/losses of the actual contract cost, relative to the target contract cost, that the client pays/receives to/from the principal contractor.

Table 3.5 The tender bid parameters and pricing mechanism formulae relevant to the three modelled contract strategy options

The following four steps outline the model's operation, common to all three contract strategy options, which lead to the calculation of the price of the contract between the client and the principal contractor:

1. each cost element that the principal contractor is contracted to complete is to be estimated as the cost to the principal contractor (note: each element is estimated as a triangular probability distribution of values);

2. the model accumulates the cost estimates using Monte Carlo simulation to produce a histogram which represents a probability distribution of the principal contractor's contract costs (i.e. actual contract costs);
3. the calculated distribution of the principal contractor's contract costs are displayed to aid the user to estimate values of the tender bid parameters particular to the contract's pricing mechanism type (note: each* tender bid parameter is estimated as a triangular probability distribution of values);
4. during the subsequent Monte Carlo simulation the sampled values in each simulation are used to calculate the contract price using the appropriate pricing mechanism formula.

The input variables in the above operation require the user to take the perspective of the principal contractor. Firstly, the actual production costs involved in the principal contractor's contract have to be estimated as costs to the principal contractor. Secondly, the user is required to estimate the values of the contract's relevant tender bid parameters. This second set of estimates require an assessment and forecast of bidding strategies that may be adopted by potential principal contractors. A contractor's bidding strategy aims to secure a contract price which covers the actual contract costs and provides the contractor with an adequate profit (i.e. mark-up).

Mark-up estimation has been extensively researched and several bidding theories exist. Skitmore (1989) and Harris and McCaffer (1995) reviewed and analysed competitive fixed price type bidding strategies. Meanwhile Chapman and Ward (1994), Jafaari (1996) and Chapman and Ward (1997) have described and suggested bidding theories pertaining to incentive and cost-reimbursable type pricing mechanisms. However, owing to its complexity, mark-up estimation is normally based upon the estimator's experience and intuition (Li, 1996).

A common conclusion prevalent in bidding theory literature is that the quality of tender bids is dependent upon the quality of the estimates of project performance (Harris and McCaffer, 1995). Therefore it appeared appropriate to give the user the flexibility to estimate the values of the relevant tender bid parameters on the basis of a distribution of contract cost aggregated from the elemental cost estimates.

Example calculation of the principal contractor's contract price

A contract strategy has to be selected for a road-bridge project. Assume the model's Traditional contract strategy option is under evaluation. The user chose to divide project construction into the following activities:

- foundations and abutments
- deck
- surface road

* the sharing rate (b) is fixed at a single value because it is assumed that this value is dictated by the client

Within the Traditional option, the contract between the client and the principal contractor involves construction. Therefore the model prompts the user to estimate each construction activity's cost to the principal contractor (i.e. general contractor). Assume the estimates shown in Table 3.6 were inputted into the model.

	Cost (£million) to the general contractor		
Construction activity	Minimum	Most likely	Maximum
foundations and abutments	0.90	1.00	1.20
deck	0.65	0.70	0.80
surface road	0.25	0.30	0.35

Table 3.6 Construction cost estimates assuming the Traditional contract strategy is used to procure the bridge project

The model performs Monte Carlo simulation to sum these three estimated distributions to obtain a distribution estimate of the general contractor's total contract costs (Figure 3.4). The model displays the calculated distribution to aid the user to estimate the values of the relevant tender bid parameters. Since the Traditional contract strategy is under evaluation, the tender bid parameters are those listed in Table 3.7. This table also displays the user's estimates of the tender bid parameters' values.

The estimated values in Table 3.7 derive from judgements based upon the general contractor's total contract cost (displayed graphically in Figure 3.4). The most likely Target contract cost is taken as the mean value of the contractor's total cost (i.e. £2.050M). The minimum and maximum target cost values were estimated at +/-£100k difference from the mean total cost value. The approximate level of the contractor's target fee was estimated at 5% of the mean total cost value. Therefore the minimum, most likely and maximum Target fee values were estimated as £0.095M, £0.100M and £0.110M. Given that the Target fee level would be approximately £0.1M and that the maximum total cost value is £2.270M it was deemed appropriate to estimate the minimum, most likely and maximum GMP values at £2.200M, £2.3000M and £2.400M, respectively.

Tender bid parameter	minimum	most likely	Maximum
Guaranteed maximum price (G)	£2.2M	£2.3M	£2.4M
Target contract cost (T)	£1.950M	£2.050M	£2.250M
Target fee (F)	£0.095M	£0.100M	£0.110M
Sharing rate (b) *		0.5	

* sharing rate (b) is assumed to be a deterministic variable (estimated as a single value)

Table 3.7 Estimates of the tender bid parameters' values for the Traditional option

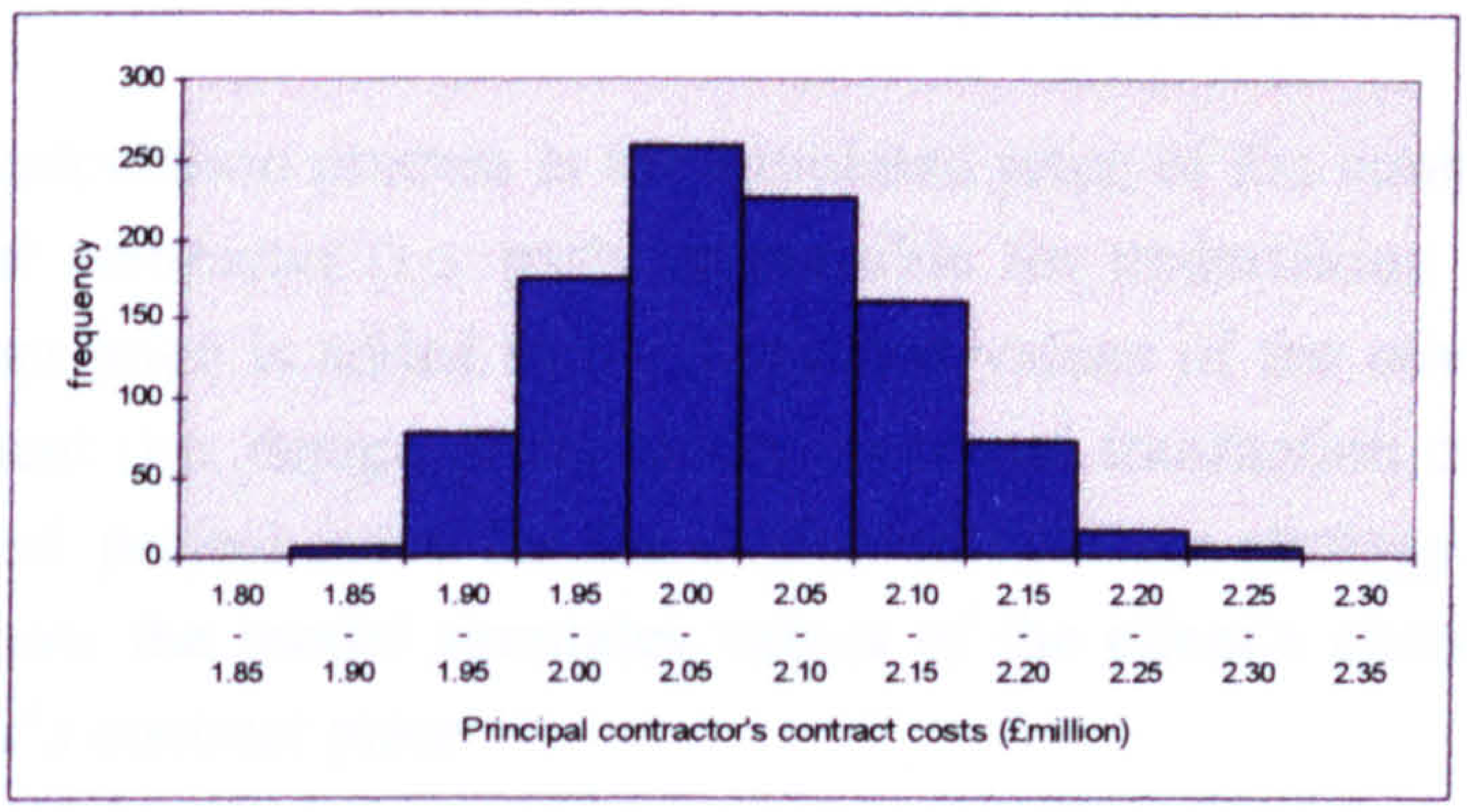


Figure 3.4 The calculated distribution of the principal contractor's contract costs

Once the tender bid estimates are inputted, the model performs Monte Carlo simulation again. In each simulation the model randomly samples values from the distributions of the relevant variables (i.e. those that feature in the relevant pricing mechanism type formula). An example contract price calculation for the Traditional contract strategy is provided below. For this example, assume the randomly sampled values from the inputted distributions in a single simulation are those displayed in Table 3.8.

Variable	Randomly sampled value
Foundations and abutments (X)	£1.027M
Deck (Y)	£0.781M
Surface Road (Z)	£0.271M
Target contract cost (T)	£2.045M
Target fee (F)	£0.102M
Guaranteed maximum price (G)	£2.269M

Table 3.8 A set of values sampled in a single simulation

Actual contract cost to the general contractor (C) = X + Y + Z

= £2.079M

Contract pricing mechanism formula = C + F + b(T – C)

= £2.079M + £0.102M + 0.5(£2.045M - £2.079M)

= £2.164M

£2.164M < £2.269M (i.e. simulated value of G)

hence,

Simulated contract price = £2.164M

The result of this calculation process is the simulated price of the contract between the client and principal contractor (i.e. party responsible for undertaking the construction work). This contract price is added to the simulated values of the other cost elements incurred by the client (i.e. design price, tender costs and transaction costs) in order to obtain the simulated project price for the evaluated contract strategy. The following sections describe how the model simulates values of the client's costs, other than the principal contractor's contract price.

3.3.2.3.1.2 Calculation of the price of an independent design contract

This analysis applies to the Traditional and Management Contract options within the model. Under the Design-Build option the design price would have been accounted for in the analysis described in the preceding section.

It was decided to simply model the price of an independent design contract as a lump sum amount. Therefore the model prompts the user to directly estimate the price which the client is likely to pay for design services, as a triangular probability distribution of values. Hence the price of an independent design contract in each simulation is simply the randomly sampled value from the estimated distribution.

3.3.2.3.1.3 Calculation of the price of the management services contract

The client appoints a management contractor under the Management Contract option to act solely in a supervisory role. Unlike the independent design contracts, it was decided not to model the management contractor's fee simply as a lump sum amount. Instead, the fee determination mechanism was defined in such a way that it may be modelled as a mathematical function similar to those of the pricing mechanisms.

In the description of the Management Contract option, the following reference was made to the management contractor's fee:

> The pre-construction fee is a lump sum, while the fee for services during construction is based on a target cost arrangement where the management contractor receives a percentage value of the construction cost, but any cost savings or overruns relative to a negotiated target cost are shared equally between the client and management contractor.

Therefore the mathematical formula used to calculate the management contractor's fee in each simulation is:

$$S + kC + b(T - C) \qquad \text{(Equation 3.1)}$$

where:

S = management contractor's pre-construction lump sum fee
k = percentage fee level
C = actual construction cost
b = sharing rate (= 0.5)
T = target construction cost

A value for each variable in the above equation (with the exception of the sharing rate, b) is randomly sampled from their estimated triangular distribution in each simulation.

3.3.2.3.1.4 Calculation of the tender process cost and transaction costs

Both of these cost elements, borne by the client, are simply estimated as triangular probability distributions of values. Hence the tender process cost and the transaction costs in each simulation assume the values randomly sampled from their corresponding distributions.

3.3.2.3.2 Project duration

At this stage of the model's operation the user is prompted to specify the schedule links between the previously-cited project activities. A project's programme is effectively modelled as a precedence diagram. Therefore the relationships between the activities can be represented by the following types of links (Pilcher, 1992):

- Start - Start
- Finish - Start
- Start - Finish
- Finish - Finish

The model allows each lag to be simulated either as a percentage completion of the precedent activity or as a specified duration.

The duration of each activity is estimated as a triangular probability distribution of values. Each activity link is specified as a single value. The model randomly samples values for each activity's duration in each simulation. The model then performs standard deterministic schedule analysis within each simulation.

Standard deterministic schedule analysis is demonstrated in the following example. The example also shows the model format used to define a project's schedule.

Example schedule analysis

The analysis is applied to the example bridge project used to demonstrate contract price calculation in section 3.3.2.3.1.1. Figure 3.5 illustrates the project schedule estimated in the form of a precedence diagram. The schedule is inputted into the model using the format shown in Table 3.9. Table 3.10 displays the calculation process used to calculate the start and finish time of each activity. The project duration equates to the latest activity finish time. Therefore in this example analysis, the project duration is 59 weeks (finish time of the surface road activity).

3.3.2.4 When to apply the model

The model is intended to be applied, primarily, at the outset of projects (i.e. before a significant contract strategy commitment is made). However, the model principles may be applied at every project stage. Figure 3.6 shows an example set of stages at which it may be useful to apply the model.

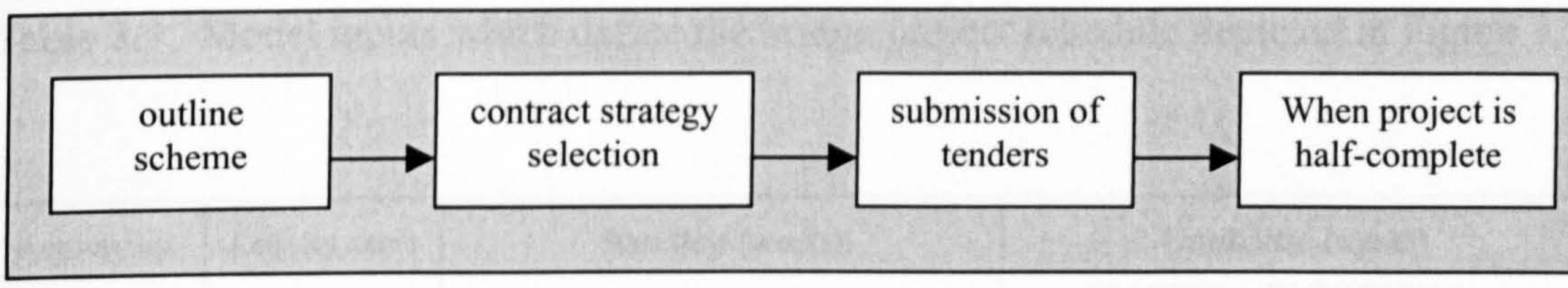


Figure 3.6 An example set of project stages at which the model may be applied

At the first stage in Figure 3.6, 'outline scheme', the model may be used to compare different project concepts (e.g. different building types, different routes for a prospective road, etc.). At the final stage in Figure 3.6 the project is half-completed. Although, at this stage, the selected contract strategy is defined and the cost and time uncertainty would have reduced, the model analysis may still prove useful in the management of the remaining project work.

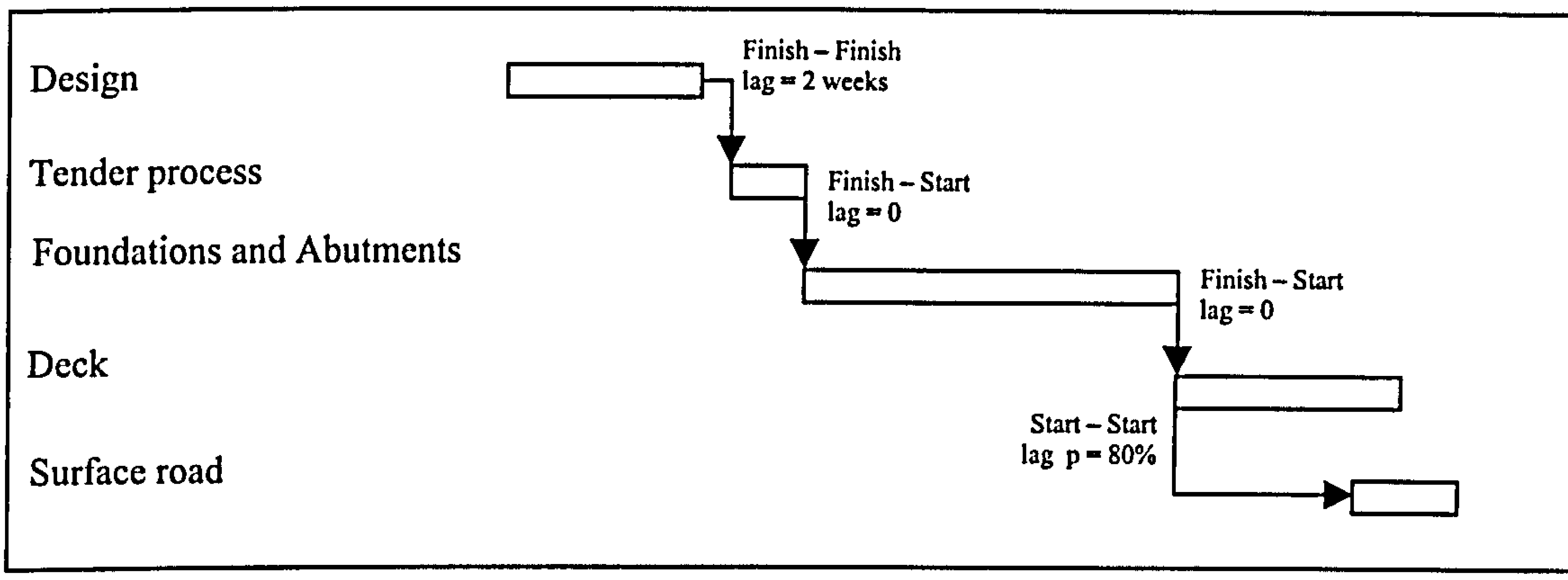


Figure 3.5 The bridge project schedule

Activity no.	Activity name	Activity Duration	Precedent Activity	Schedule links (lags)											
				START-START			FINISH-START			START-FINISH			FINISH-FINISH		
				p	w	d	p	w	d	p	w	d	p	w	d
1	Design	13	(start)					0							
2	Tender	5	1											2	
3	Found. & Abuts.	25	2					0							
4	Deck	15	3					0							
5	Surface road	7	4	80											

(Note: each activity may be linked to a maximum of three precedent activities)

Key:
p = percentage completion of precedent activity
w = number of weeks
d = number of days

Table 3.9 Model inputs which define the bridge project schedule depicted in Figure 3.5

Activity no.	Activity name	Start time (weeks)	Finish time (weeks)
1	Design	0	START(1) + DURATION(1) = 0 + 13 = 13
2	Tender	FINISH(2) – DURATION(2) = 15- 5 = 10	FINISH(1) + LAG = 13 + 2 = 15
3	Found. & Abuts.	FINISH(2) + LAG = 15 + 0 = 15	START(3) + DURATION(3) = 15 + 25 = 40
4	Deck	FINISH(3) + LAG = 40 + 0 = 40	START(4) + DURATION(4) = 40 + 15 = 55
5	Surface road	START(4) + 80% DURATION(4) = 40 + (0.8 x 15) = 52	START(5) + DURATION(5) = 52 + 7 = 59

Table 3.10 Calculation of the project activities' start and finish times

Obviously the work presented in this thesis has focused upon the second stage in Figure 3.6, 'contract strategy selection'. However, another important stage, which is regarded as integral to contract strategy selection, is where contractors' tenders are submitted. At this stage the user can find out whether the client's analysis agrees with the contractors' predictions of project performance that is reflected in their tender bids. If they do not agree, the client organisation can at least take rational action (whether this involves a review of the client's analysis or making a variation to the contract strategy) on the basis of its own analysis, rather than blindly accepting a contractor's bid.

Although Figure 3.6 displays contract strategy selection as a particular project stage, it is important to appreciate that all contract strategy decisions are not taken simultaneously. Some decisions need to be taken at the project outset (e.g. those concerning organisational structure), while others can be offset until later (e.g. those relating to risk allocation, type of pricing mechanism or tender process). However, section 2.2.2 made reference to numerous sources that have acknowledged the necessity to perform a holistic evaluation of contract strategies at the project outset owing to the interdependencies between contract strategy components.

3.3.2.5 Diagrammatic representation of the model structure

Figure 3.7 presents a flowchart of the complete prototype model structure. It details which inputs are required of the user as well the operations executed by the model for each of the three modelled contract strategy options.

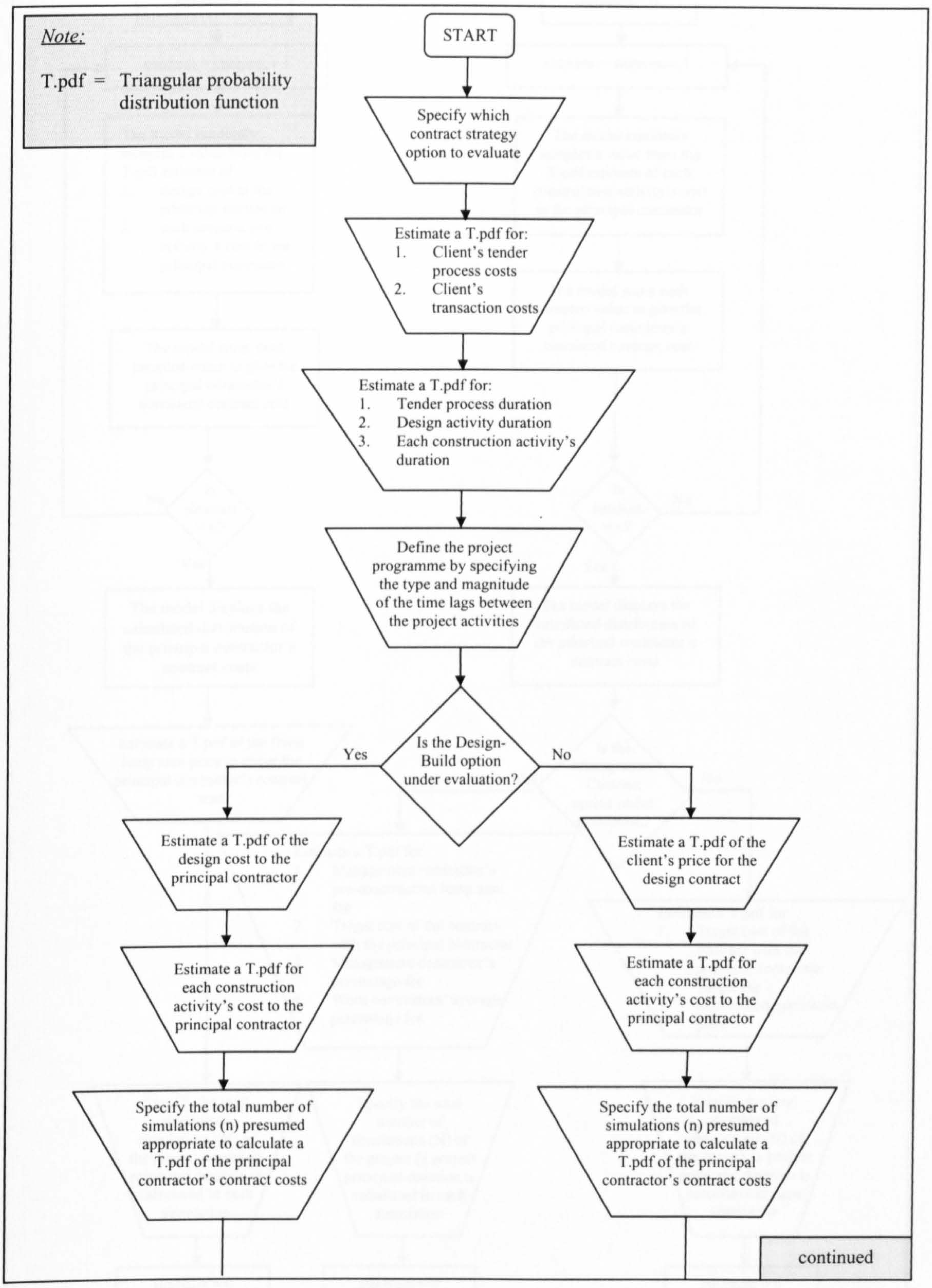


Figure 3.7 Flowchart of the prototype model structure *(continued overleaf)*

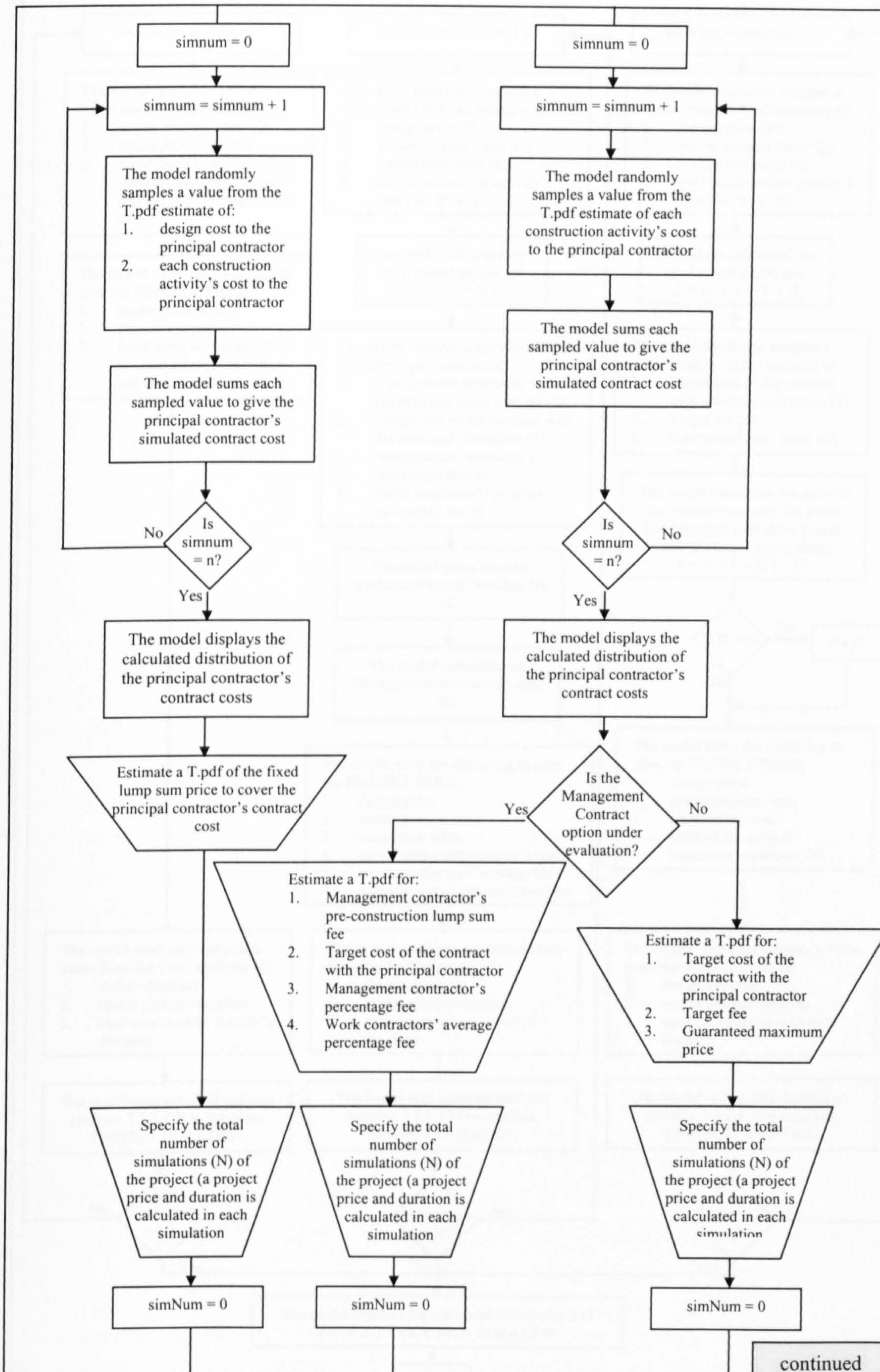


Figure 3.7*(continued)* Flowchart of the prototype model structure*(continued overleaf)*

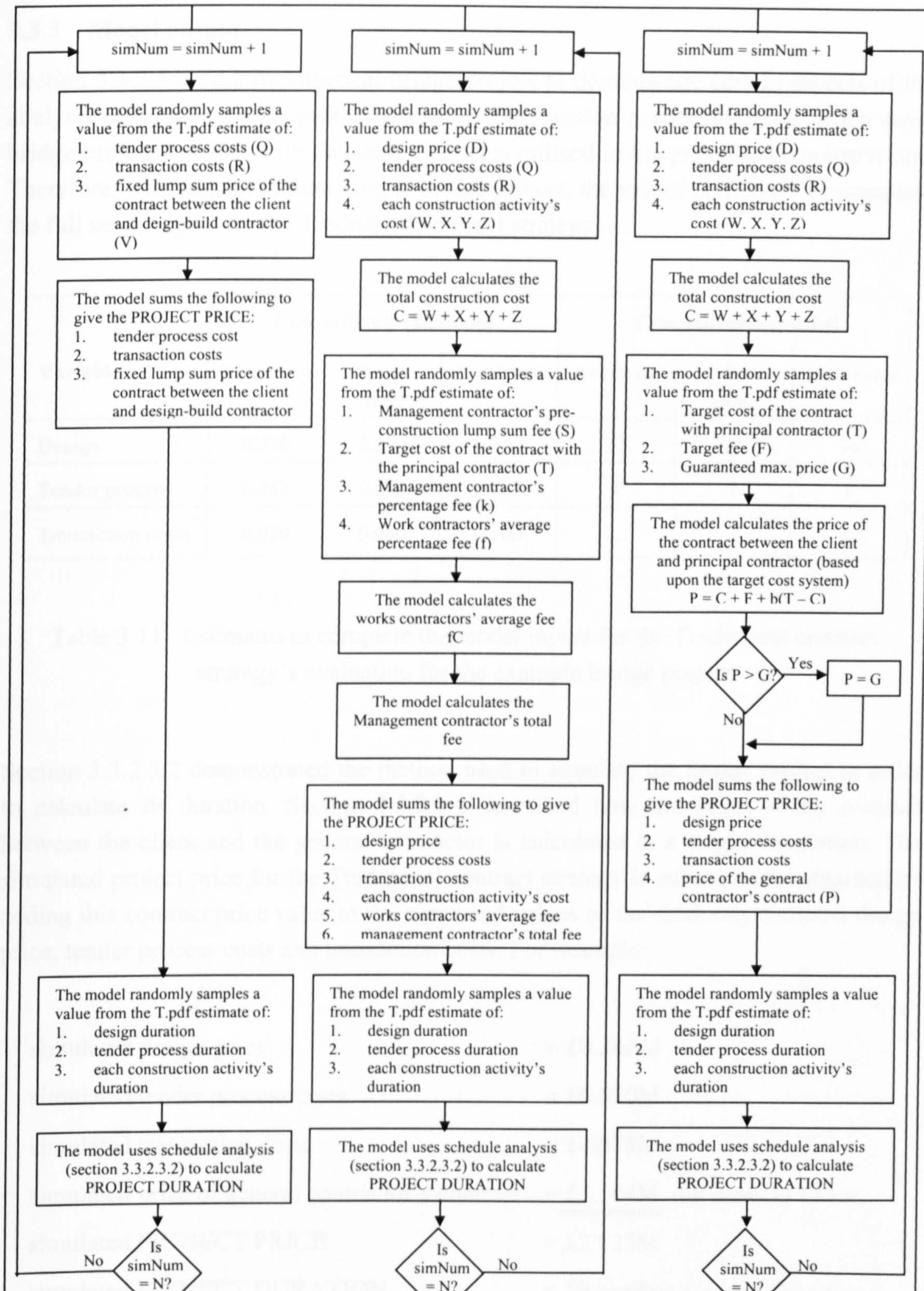


Figure 3.7*(continued)* Flowchart of the prototype model structure

3.3.3 Model output

Section 3.3.2.3 used a hypothetical bridge project to demonstrate certain aspects of the analysis performed by the prototype model. This section makes reference to the same bridge project together with the same estimates utilised in the previous demonstrations. Therefore, with respect to the example bridge project, the values in Table 3.11 complete the full set of inputs for the Traditional contract strategy.

Variable	Cost estimate (£million)			Time estimate (weeks)		
	Minimum	Most likely	Maximum	minimum	Most likely	Maximum
Design	0.220	0.250	0.300	12	13	16
Tender process	0.018	0.020	0.022	4	5	6
Transaction costs	0.070	0.080	0.100	--	--	--

Table 3.11 Estimates to complete the model inputs for the Traditional contract strategy's evaluation for the example bridge project

Section 3.3.2.3.2 demonstrated the method used to simulate the bridge project in order to calculate its duration. Section 3.3.2.3.1 described how the price of the contract between the client and the general contractor is calculated in a single simulation. The simulated project price for the Traditional contract strategy is subsequently obtained by adding this contract price value to the simulated values of the randomly sampled design price, tender process costs and transaction costs. For example:

simulated design price	= £0.266M
simulated tender process costs	= £0.020M
simulated transaction costs	= £0.075M
simulated price of general contractor's contract	= £2.164M (see section 3.3.2.3.1.1)
simulated PROJECT PRICE	= £2.525M
simulated PROJECT DURATION	= 59 weeks (see section 3.3.2.3.2)

The following sub-sections use the example bridge project together with estimates for the Traditional option to demonstrate how the results of the simulation can be presented and interpreted.

3.3.3.1 Presentation of the model output

In the preceding section a simulated project price and duration were obtained. The results of the single simulation can be presented as shown in Figure 3.8a. The single point in Figure 3.8a represents one simulation of the project using the Traditional contract strategy. Figure 3.8b shows the results of 1000 project simulations.

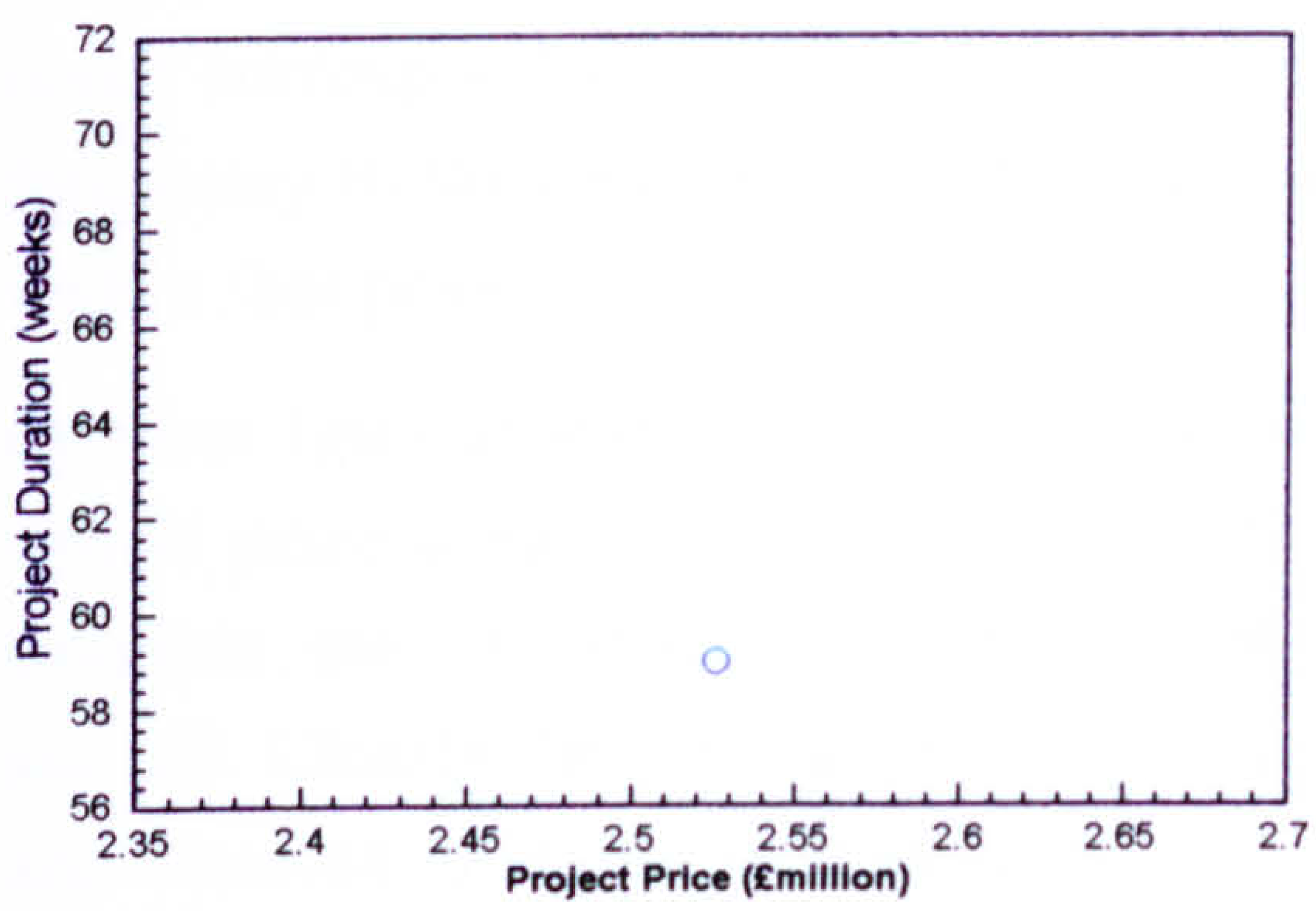


Figure 3.8a The result of a single simulation (i.e. a project price and duration value)

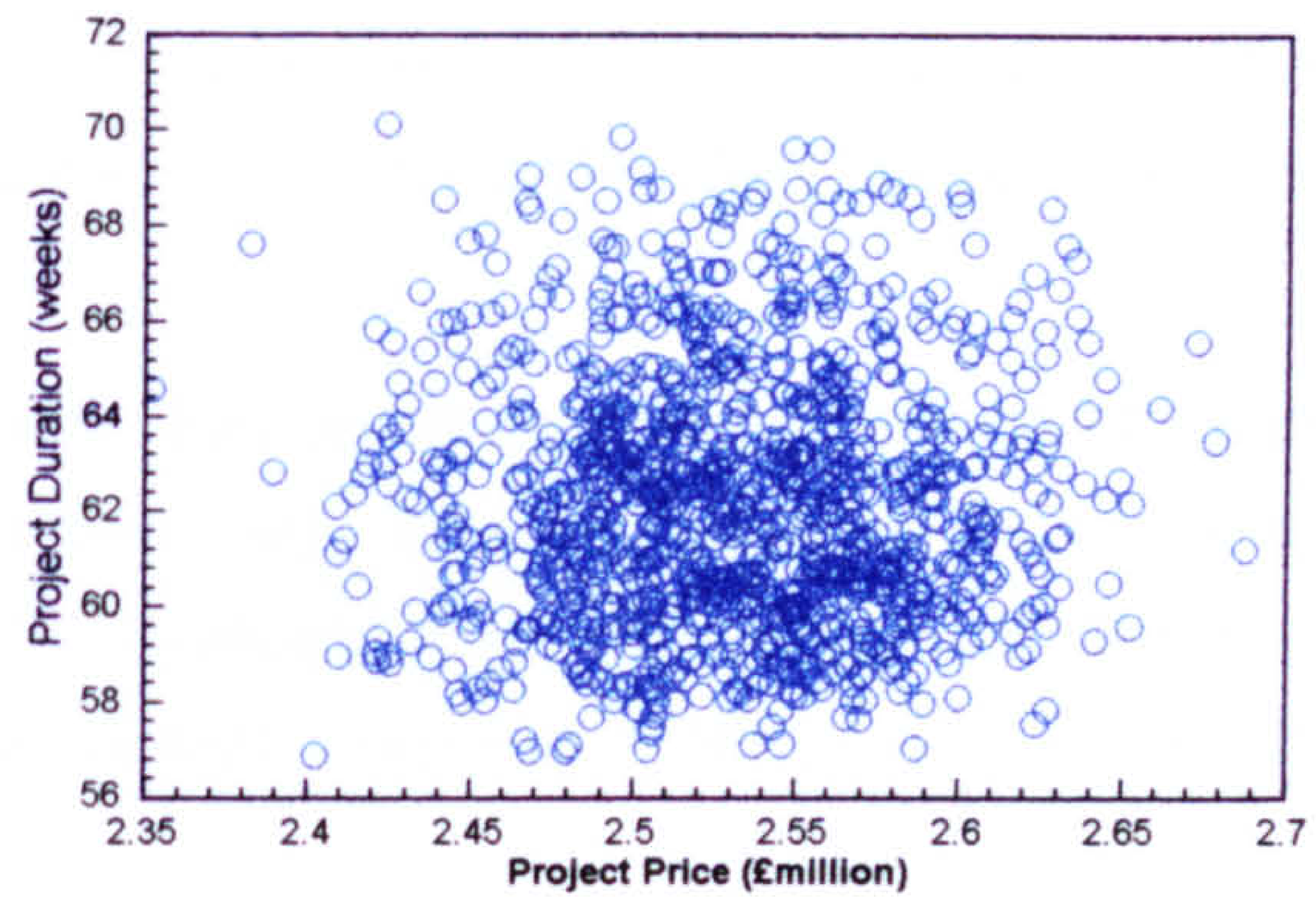


Figure 3.8b One thousand simulation results (i.e. 1000 project price and duration values)

The scatter plot of example results in Figure 3.8b indicates that certain price and duration values were calculated more frequently than others amongst the 1000 simulations. It is possible to display the results as histograms and contour plots to clearly indicate which ranges of price and duration values were simulated more frequently than others.

A histogram displays the number of simulated price or duration values that lie within certain intervals (see Figures 3.9a and 3.9b). Alternatively, contour plots accommodate the fact that each simulated result comprises both a project price and duration value. The remainder of this section describes how a contour plot can be generated from 1000 simulated results.

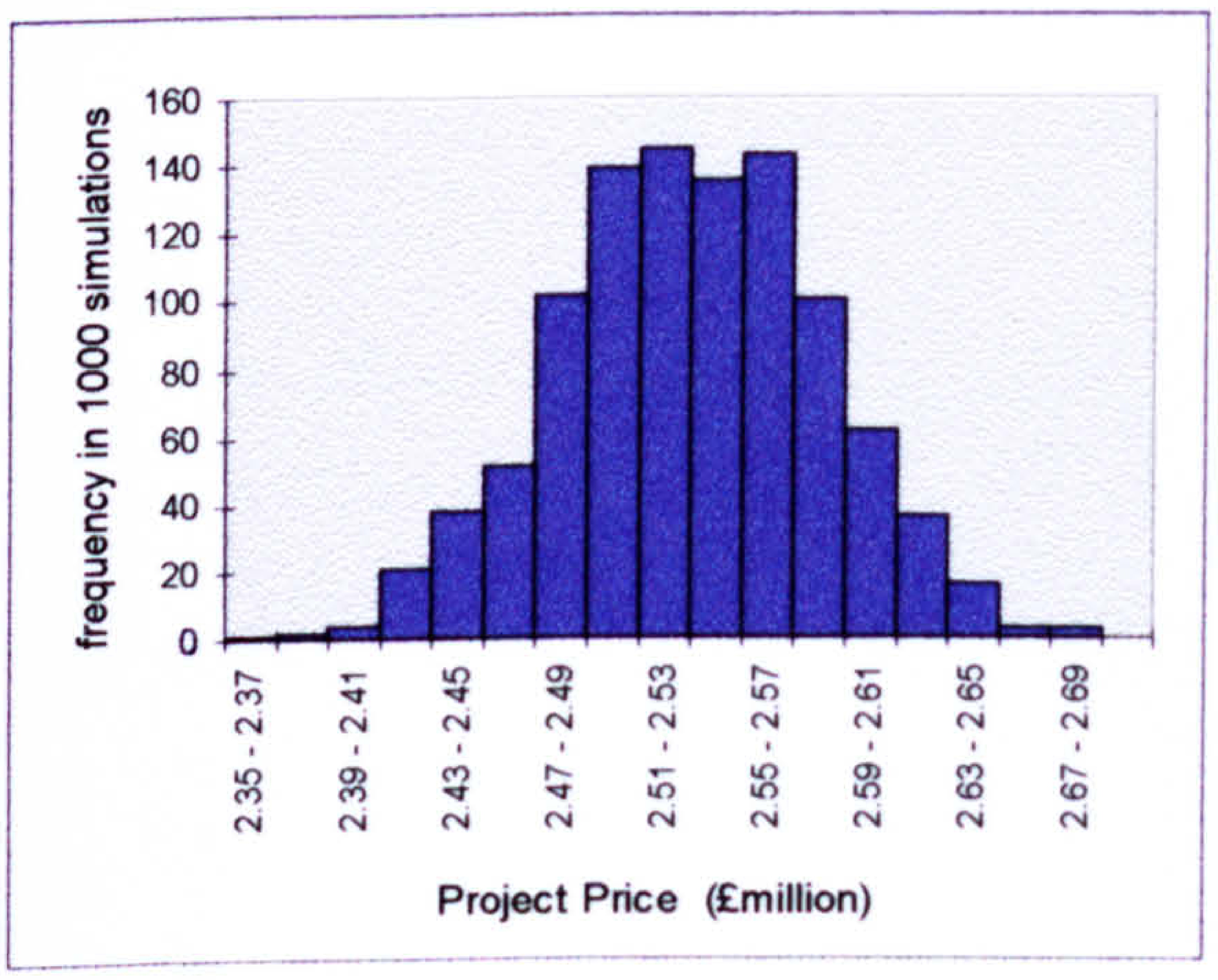


Figure 3.9a A histogram plot of the project price results displayed in Figure 3.8b

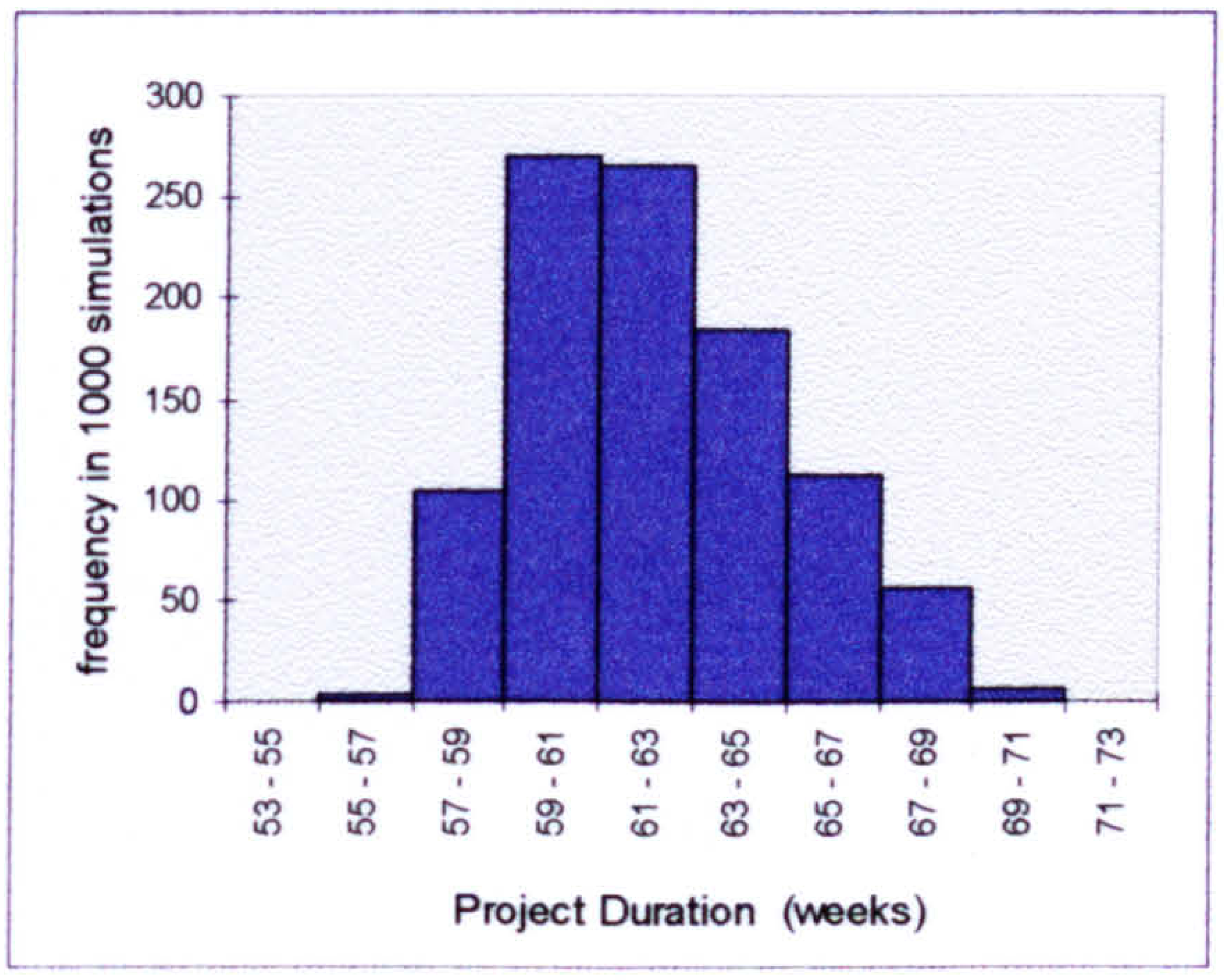


Figure 3.9b A histogram plot of the project duration results displayed in Figure 3.8b

The first step in generating a contour plot is to establish a set of intervals in matrix form. Each matrix row corresponds to a project price interval while each matrix column corresponds to a project duration interval (see Table 3.11i). In simple statistical terms, each matrix entry equates to a price-duration bin. These bins are used to tally each simulated result.

When all of the results have been tallied, the matrix displays the frequency with which a result corresponded to each price-duration bin (see Table 3.11i). The ratio of each bin's frequency to the total number of results equates to the probability that a result will occur within that price-duration bin.

Contour lines at selected frequency levels may then be interpolated. Table 3.11i shows which price-duration bins are contained within each of three contour intervals. For example, the bins shaded yellow in Table 3.11i correspond to a frequency of between 10 and 20. Clearly, this means of presenting the results would be more precise if the price and duration intervals were smaller.

An approximate estimate of the cumulative probability of the simulated results at each contour level can be calculated as the following ratio:

$$\frac{\text{number of results within the specified contour interval}}{\text{total number of simulated results}}$$

Figure 3.10 shows the cumulative percentile level at each of the three contour lines.

The contour plots presented subsequently in the thesis were obtained using Stanford Graphics software. This package interpolates a data matrix, like that shown in Table 3.11i, to establish a series of frequency contours.

Project Duration (weeks)	2.38 - 2.4	2.4 - 2.42	2.42 - 2.44	2.44 - 2.46	2.46 - 2.48	2.48 - 2.5	2.5 - 2.52	2.52 - 2.54	2.54 - 2.56	2.56 - 2.58	2.58 - 2.6	2.6 - 2.62	2.62 - 2.64	2.64 - 2.66	2.66 - 2.68
70 - 71	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
69 - 70	0	0	0	0	1	3	1	2	3	2	2	4	0	0	0
68 - 69	0	0	0	0	3	1	4	5	5	4	2	0	1	0	0
67 - 68	0	0	0	0	3	5	5	6	3	6	5	4	2	2	0
66 - 67	0	0	0	3	2	5	3	6	13	7	7	2	2	3	0
65 - 66	0	0	0	3	3	2	17	13	12	14	12	5	2	2	0
64 - 65	0	0	0	5	5	11	22	14	12	17	9	7	5	2	0
63 - 64	0	0	1	6	3	11	15	27	22	19	13	17	5	4	3
62 - 63	0	1	1	1	9	12	15	23	26	13	15	7	11	3	0
61 - 62	0	0	0	0	6	8	18	21	27	26	25	19	5	4	1
60 - 61	0	0	0	4	4	13	11	12	14	21	16	11	6	2	1
59 - 60	0	0	1	4	7	2	12	13	13	16	9	5	2	0	0
58 - 59	0	0	0	0	0	1	2	7	1	3	2	2	0	0	0
57 - 58	0	0	0	0	0	0	0	2	2	3	0	0	0	0	0
56 - 57	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

Project Price (£miilion)

Key:
- 20 +
- 10 - 20
- 0 - 10

Table 3.11i A data matrix that indicates three contour intervals

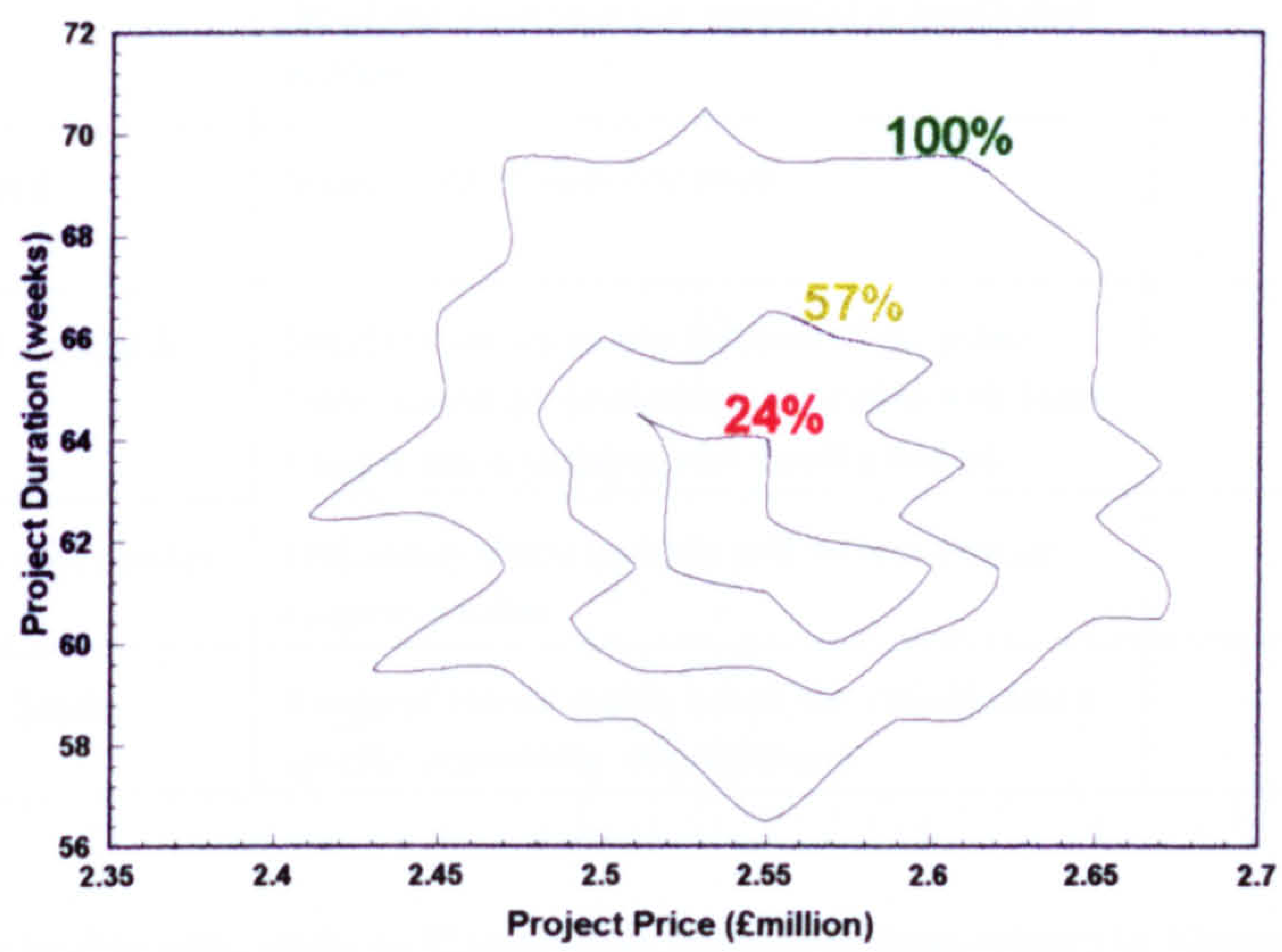


Figure 3.10 The cumulative percentiles of three contour lines derived from Table 3.11i

3.3.3.2 Interpretation of the model output to aid decision-making

Vose (1996) presented a comprehensive set of statistical techniques and measures particularly applicable to the interpretation of data calculated using stochastic simulation. The majority of these are listed and described in Table 3.12.

Statistical measure	Description	Formula
Mode	Value with highest probability (i.e. most likely to occur)	
Median	Value at which the variable has equal probability (0.5) of being above or below (i.e. 50th percentile)	
Mean	Average/expected value	$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$
Conditional mean	Expected value of a portion of a distribution	
Variance	Average of the squared distance of all the variable's values from the mean*	$V = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}$
Standard deviation	Square root of the variance*	$\sigma = \sqrt{V}$
Range	Difference between a variable's maximum and minimum values	
Mean deviation	Average of the absolute differences between the variable's values and their mean (note: in same units as the variable)*	$MD = \frac{\sum_{i=1}^{n} \lvert x_i - \bar{x} \rvert}{n-1}$
Semi-variance	The variance of a variable above/below a threshold value (x_o) (i.e. spread of a distribution portion)	$V_s = \frac{\sum_{i=1}^{k} (x_i - x_o)^2}{k}$
Semi-standard deviation	Square root of semi-variance	$\sigma_s = \sqrt{V_s}$
Normalised standard deviation	Standard deviation as a fraction of the mean (note: useful for comparing a variable with large $\bar{x}$ and σ and a variable with small $\bar{x}$ and σ)	$\sigma_n = \frac{\sigma}{\bar{x}}$
Cumulative percentiles	Probability that a variable will be less than or equal to a value	
Confidence limits	Range of values within which the variable has a specific probability of occurrence	

* Applicable principally to Normal distributions or approximately Normal distributions. Rees (1995) stated that a distribution is approximately Normal when the following criteria are satisfied:

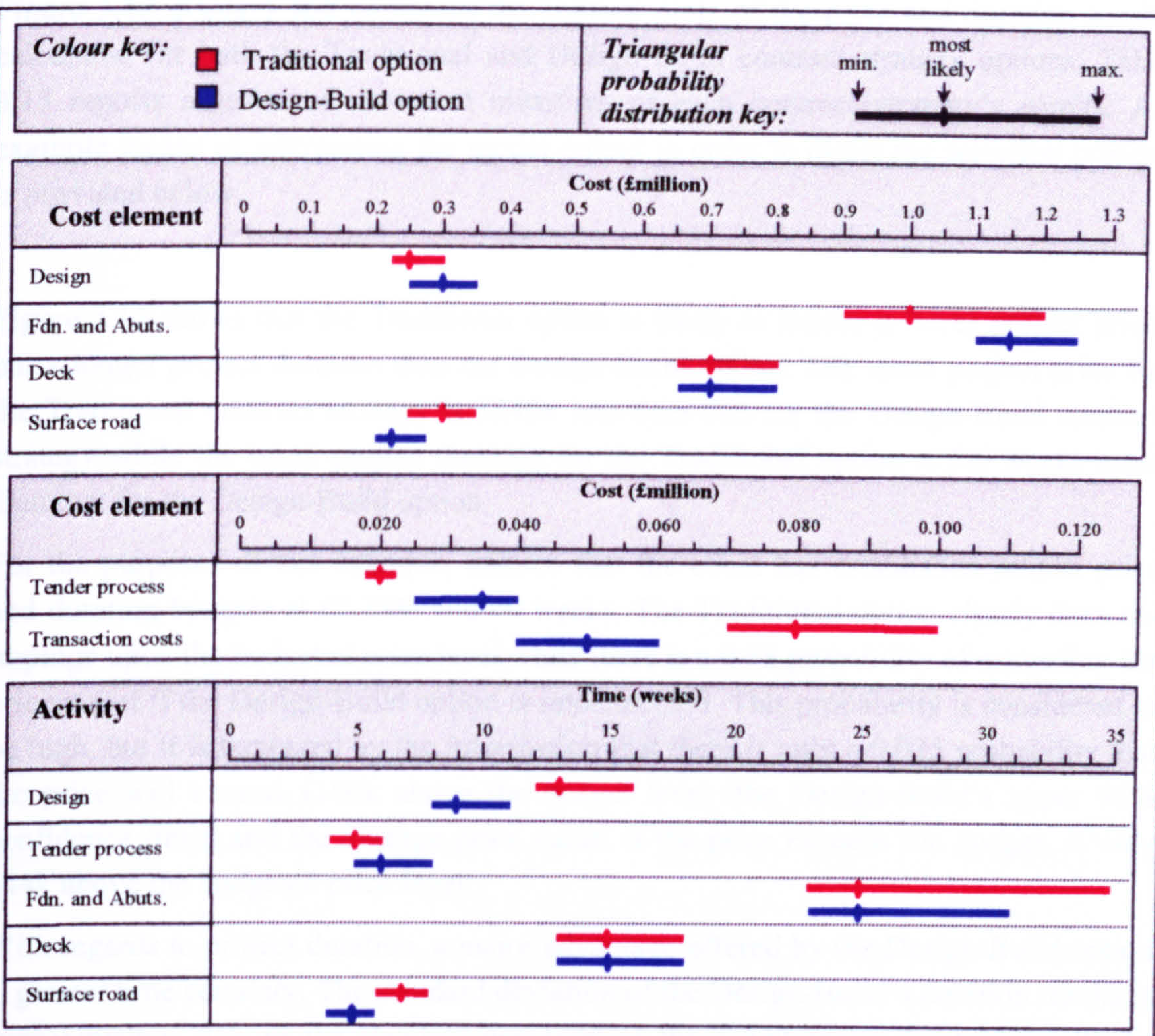
approx. 68% of the area lies within one standard deviation of the mean
approx. 95% of the area lies within two standard deviations of the mean
approx. 99.7% of the area lies within three standard deviations of the mean

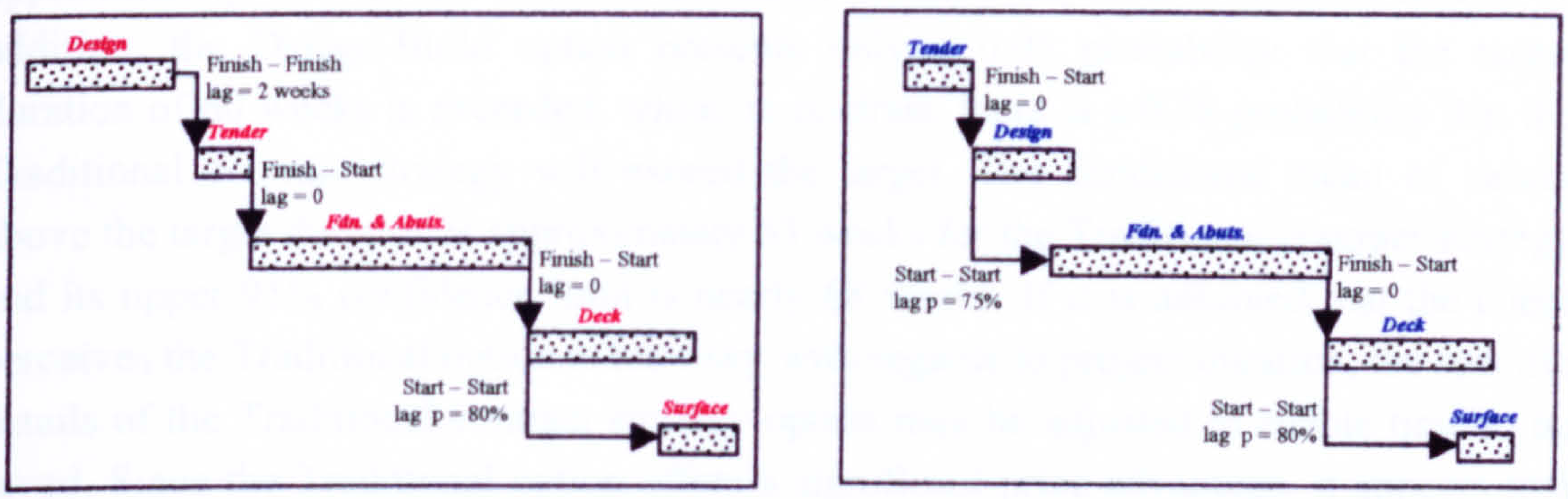
Table 3.12 Statistical measures that can be used to interpret the model output

Example analysis application and interpretation of the model output

In this example, the results previously-calculated from the evaluation of the Traditional contract strategy option for the hypothetical bridge project are contrasted with results calculated from an evaluation of a Design-Build option for the same project. The reasons behind the different values estimated for the Traditional and Design-Build options (see Figure 3.11) are based upon the following hypothetical assumptions:

- The design under the Design-Build contract strategy is expected to be completed in a shorter time period than under the Traditional contract strategy and as a result the Design-Build's design cost is expected to be higher.
- When the Design-Build contractor is required to accept and cost the risk presented by the foundations and abutments activity, less information is known than when the general contractor is appointed under the Traditional arrangement. As a result the Design-Build contract strategy is assigned a higher cost estimate for this activity than the Traditional alternative. However, the time risk presented by the foundations and abutments activity is expected to be reduced under the Design-Build option because the contractor, assumed to be the party most capable of dealing with the associated risks, is able to manage the risk earlier, and thus reduce the maximum possible delay related to this activity, under the Design-Build option relative to the Traditional option.
- Neither contract strategy option is expected to offer a notable cost and time advantage with respect to the deck activity.
- A more competitive price for road surfacing materials or even for a subcontractor are expected to be procured under the Design-Build option relative to the Traditional option. Based on the same reasoning, a reduction in the road surfacing activity duration is expected to accompany the cost reduction.
- The Design-Build's competitive tender process is expected to be more costly and take longer than the Traditional's negotiated tender process. This is principally because the Design-Build tender decision pertains to a greater allocation of responsibility, a subjective evaluation of design information and an agreement of a fixed price at the project outset.
- The Design-Build option is expected to induce a lower level of transaction costs because the majority of project responsibility is delegated within the one organisation, the Design-Build contractor (see section 3.3.2.1.3).
- The estimated project schedules for the two contract strategy options differ in as much as the order and precedence links of the design and tender process activities, and also the Design-Build option facilitates some overlap between the design activity and the foundations and abutments activity.





Tender bid parameter	minimum	most likely	maximum
Guaranteed maximum price (G)	£2.200M	£2.300M	£2.400M
Target contract cost (T)	£1.950M	£2.050M	£2.250M
Target fee (F)	£0.095M	£0.100M	£0.110M
Sharing rate (b) *	0.5	0.5	0.5

Tender bid parameter	minimum	most likely	maximum
Fixed lump sum price	£1.950 M	£2.050M	£2.250M

Figure 3.11 Estimates based on the assumption that the hypothetical bridge project is procured using the Traditional and Design-Build contract strategy option

Figure 3.12 displays and compares the contour plots of the price and duration results calculated for both the Traditional and Design-Build contract strategy options. Table 3.13 reports a series of statistical measures of each contract strategy's results. An example means of interpreting the model output in order to direct the selection process is provided below.

Figure 3.12 shows that the Traditional option is likely to induce a lower project price, but a longer project duration than the Design-Build option. The mean project price for the Traditional contract strategy is £240k less than that for the Design-Build contract strategy while the mean project duration for the Traditional option is 5.6 weeks more than that for the Design-Build option.

For the purposes of this example, assume that the client has established project price and duration budgets at £2.75M and 60 weeks. The Traditional option clearly does not impinge upon the budgeted price level while there is a 0.58 probability of exceeding the price target if the Design-Build option is implemented. This probability is considered to be high, but it is tempered by the information that there is only a 0.025 probability that the price will exceed £100k above the budget level (the Design-Build's upper 95% confidence limit) and the average price value, if the price exceeds the budget, is only £44k above the budgeted price level.

With regards to project duration, a major advantage offered by the Design-Build option is greater time certainty. The standard deviation of the Design-Build's duration results is approximately 70% of the standard deviation of the Traditional's duration results. In addition, the Design-Build option presents only a 0.05 probability that the target duration of 60 weeks is exceeded, while, in contrast, there is a 0.78 probability that the Traditional contract strategy will exceed the target. The conditional mean of values above the target duration is approximately 63 weeks for the Traditional contract strategy and its upper 95% confidence limit is nearly 68 weeks. If it is assumed that the client perceives the Traditional option is too risky with regards to project duration, the specific details of the Traditional contract strategy option may be adjusted to enable time to be saved. Since the Traditional option offers a significant price advantage, it appears that the client may be well-advised to invest money to facilitate time reduction measures under the Traditional contract strategy.

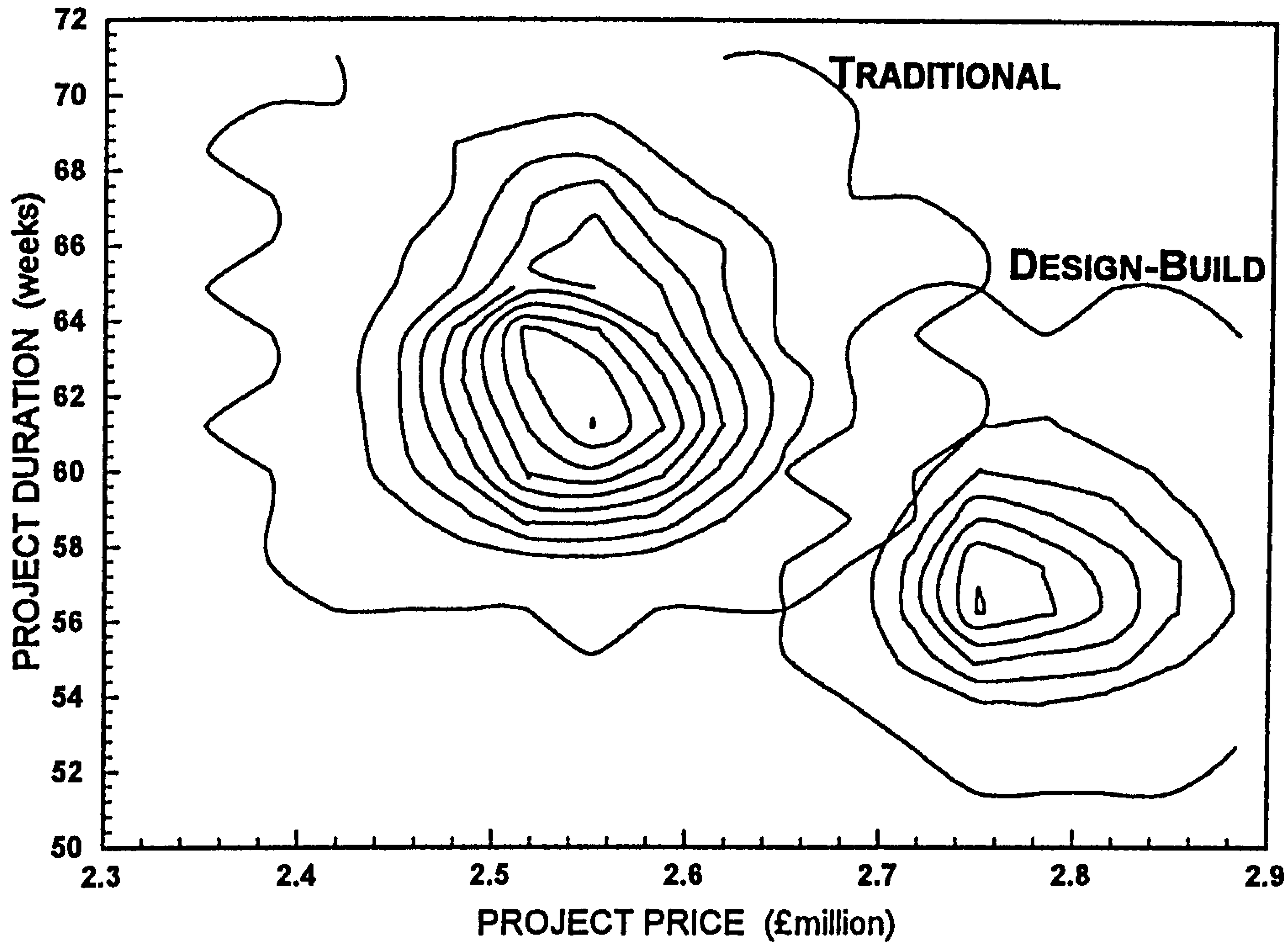


Figure 3.12 Comparison of the model output calculated for the Traditional and Design-Build contract strategy options

Statistical measure	Price		Duration	
	Traditional	Design-Build	Traditional	Design-Build
Mean	£2.530M	£2.766M	62.28wks	56.65wks
standard deviation	0.051	0.042	2.725	1.830
Minimum	£2.352M	£2.676M	56.22wks	51.42wks
Maximum	£2.692M	£2.884M	71.00wls	62.76wks
P(X > Target value)	0	0.58	0.78	0.05
[Conditional] mean of X > Target value	0	£2.794M	63.14wks	60.93wks
95% confidence limits	£2.430M – £2.630M	£2.684M - £2.848M	56.94wks – 67.62wks	53.06wks – 60.20wks

Table 3.13 Comparison of statistical measures between the Traditional and Design-Build contract strategy options

3.3.3.3 Sensitivity Analysis

Sensitivity analysis is an analytical process which aims to test whether the conclusions drawn from an analysis are likely to significantly alter if the input data and their underlying assumptions change (Thesen and Travis, 1992). This section uses the example bridge project again and the estimates provided for the Traditional contract strategy option to describe and demonstrate several techniques which can be used to undertake sensitivity analysis. Like the statistical measures featured in Table 3.12, the majority of these techniques were described by Vose (1996) as being particularly applicable to the interpretation of data calculated using stochastic simulation. It should be noted that the results and interpretation of the sensitivity analyses described in this section are specific to the hypothetical bridge project and the example model inputs. Furthermore, 1000 simulations are undertaken in the sensitivity analyses that are applied to a set of simulated results.

The spider plot in Figure 3.13 illustrates how the project price result is affected by each price element's estimated distribution of values (with exception of the tender process and transaction costs because these cost elements were insignificant relative to the others). The plotted line for each variable is produced by varying the value of the respective variable from its minimum to maximum estimate while maintaining the other input variables at their mean values. Given that the vertical axis in the spider plot registers the change in value of the output variable, it can be inferred that the greater the vertical distance covered by an input variable's plotted line, the more sensitive the output is to that input variable.

Figure 3.13 suggests that project price is unaffected by the estimated distribution of Guaranteed Maximum Price (G). This is not strictly true. It just happens that the price of the principal contractor's contract when all of the variables are set at their mean values is less than the estimated range of Guaranteed Maximum Price values. This may have been expected since the value of the Guaranteed Maximum Price is intended to protect the client from paying an excessive price, not an average price. As an aside, a simple calculation determined that there was a 0.02 probability that the actual price of the principal contractor's contract would exceed the mean value of the Guaranteed Maximum Price.

Figure 3.13 shows that project price is most, and approximately equally, sensitive to the foundations and abutments cost (X) and the target cost (T). The cause of this result can be explained with reference to the following equation used to calculate project price for the Traditional contract strategy option:

when $(X + Y + Z) + F + b(T - (X + Y + Z)) < G$

Project Price $= (X + Y + Z) + F + b(T - (X + Y + Z)) + F + D + Q + R$

Sharing rate (b) is fixed at 0.5, hence

Project Price $= 0.5T + 0.5(X + Y + Z) + F + D + Q + R$

The above equation shows that the same proportion (0.5) of T and X contribute to the project price value. Therefore because the estimated distributions of T and X both cover the same range magnitude (£300k) and the same distribution shape (see Tables 3.6 and 3.7), the project price is equally sensitive to the foundations and abutments cost (X) and the target cost (T). Since the range magnitude covered by T and X are greater than that covered by the other variables the project price is most sensitive to T and X. Essentially the same principles reason why the project price sensitivity to the design cost (D) and deck cost (Y) are roughly equal second highest.

Figure 3.14 is a tornado chart that reiterates the sensitivity results depicted in the spider plot. The tornado chart plots the Spearman's rank correlation coefficient between each variable and the project price. The higher a variable's correlation coefficient the greater the effect that the variable has on the model output.

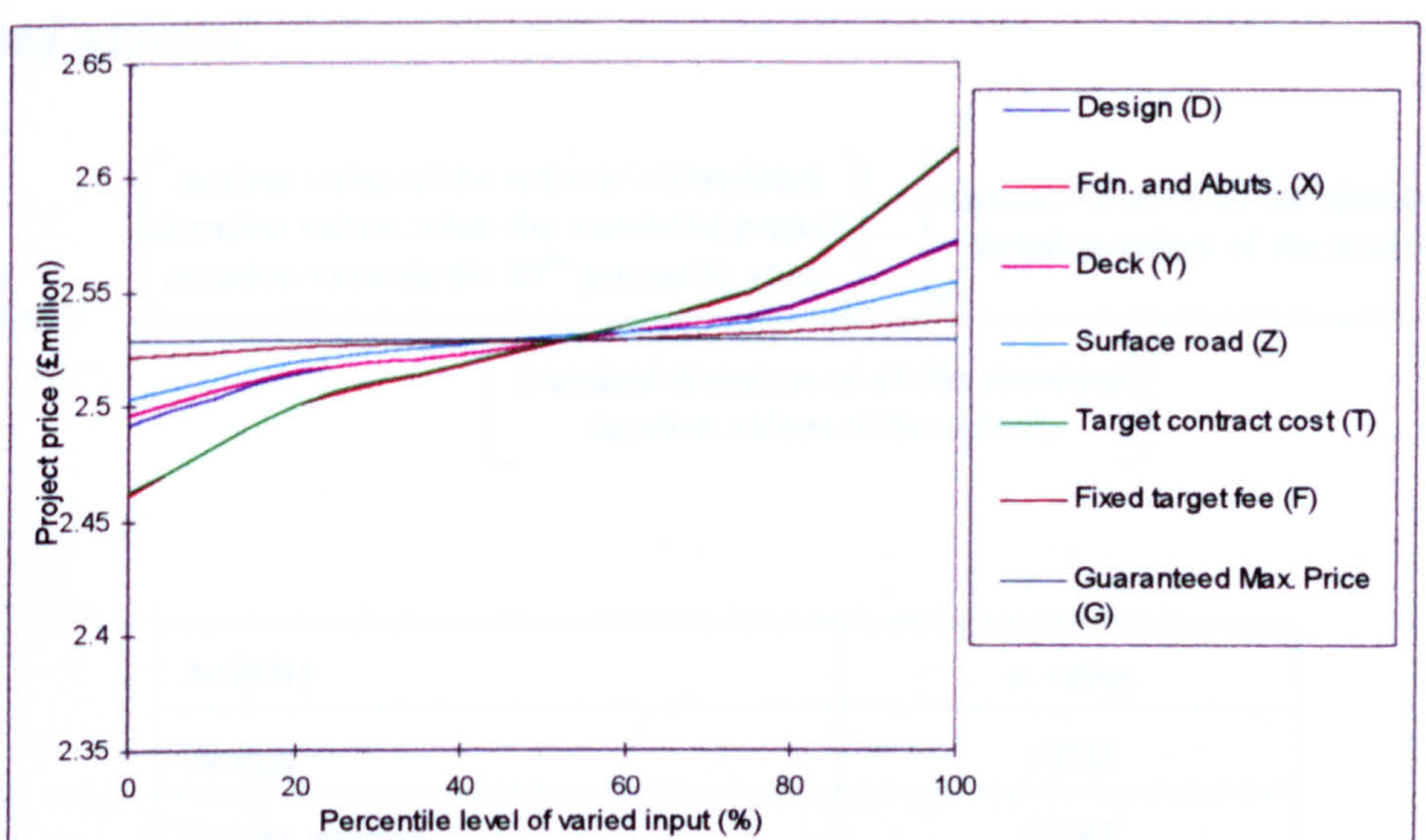


Figure 3.13 A spider plot which indicates the relative sensitivity of the project price to the cost elements (with the exception of tender process and transaction costs)

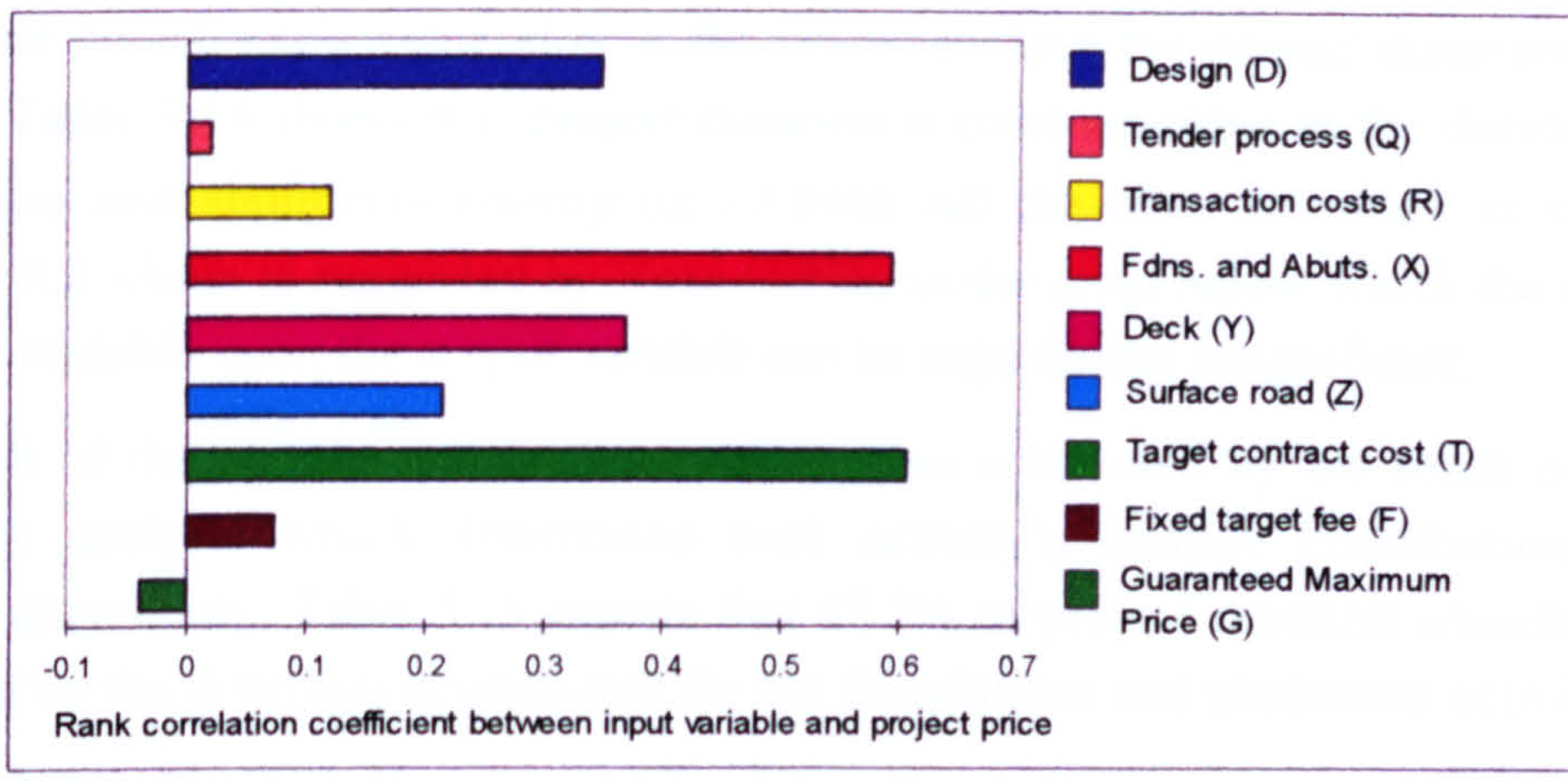


Figure 3.14 A tornado chart indicating the sensitivity of the price to the cost elements

Table 3.14 reports the results of a conditional median analysis on the Traditional contract strategy's project duration results for the bridge project. The analysis determined the relative extent to which each project activity generates a simulated project duration which exceeds the 85th cumulative percentile value of the project duration distribution. This measure (α), for each activity, is calculated using the following equation:

$$\alpha = \frac{\left[\begin{array}{c}\text{median value of the activity's simulated}\\ \text{duration values when the simulated project}\\ \text{duration exceeds the } 85^{\text{th}} \text{ percentile value}\end{array}\right] - \left[\begin{array}{c}\text{median value of all the simulated}\\ \text{duration values of the activity}\end{array}\right]}{\left[\begin{array}{c}\text{Standard deviation of all the simulated}\\ \text{duration values of the activity}\end{array}\right]}$$

Activity	α value
Design	0.038
Tender process	0.243
Foundations and Abutments	1.946
Deck	0.218
Surface road	0.341

Table 3.14 The results of a conditional median analysis on the example project duration results

The higher an activity's value of α is, the more sensitive the project duration is to that activity. Table 3.14 shows that project duration is most sensitive to the duration of the foundations and abutments activity ($\alpha = 1.946$). All the other activities' α values are less than 0.5 which is suggested by Vose (1996) as the level below which the impact of the input variable upon the output variable can be regarded as insignificant.

The result of the conditional median analysis was reinforced by the result of another sensitivity analysis which determined each activity's relative contributions to the duration uncertainty. Table 3.15 reports that 85.7% of project duration uncertainty was generated by the distribution estimated for the foundations and abutments activity.

The results in Table 3.15 were obtained by determining the reduction in standard deviation of the simulated project duration values when each activity, in turn, was set at its mean value. Each activity's normalised change in standard deviation was subsequently calculated by dividing the change in standard deviation induced by each activity by the sum of the standard deviation reduction induced by all of the activities.

Variable set to mean	Standard deviation	Change in standard deviation	Normalised change
--	2.725	--	--
Design	2.583	0.142	7.4%
Tender process	2.723	0.002	0.1%
Fdns. and Abuts.	1.090	1.635	85.7%
Deck	2.635	0.090	4.7%
Surface road	2.685	0.040	2.1%

Table 3.15 The results of a sensitivity analysis to determine the relative extent to which each activity generates the uncertainty in the project duration results

In some respects the results of the sensitivity analyses described in this section could have been predicted without the application of the techniques. The largest and most uncertain input variables were clearly going to affect the output variables the most. Nonetheless, in more detailed applications of the model analysis, sensitivity analysis may offer more valuable insights.

It is important, however, to remain aware that owing to the nature of contract strategy selection the analysis will inevitably be highly subjective and uncertain. Therefore it is intended that the model analysis be applied and interpreted efficiently. In other words it is advised not to perform over-elaborate applications of the analysis, instead, take advantage of the quantitative and probabilistic nature of the analysis to test theories and gain less-intuitive insights to aid decision-making.

3.3.3.3.1 Sensitivity of the analysis results to the number of simulations

In this chapter, whenever reference was made to a set of simulated results, 1000 has always been cited as the number of simulated results. The decision to perform 1000 simulations was a conservative estimate intended to ensure that the number of resultant values would generate a distribution sufficiently equivalent to the distribution that would be obtained if the input distributions could be combined with absolute precision.

Law and Kelton (1991) described a method which aimed to ascertain the number of simulations required to estimate the actual mean result value within a specified error. This method involved performing a number of independent simulation runs, where each run comprised a specified number of simulations. The intention was to measure whether each run's mean value exceeded a specified error. A test, based on similar principles, was undertaken to check the consistency of the calculated price and duration results for the example bridge project when the results comprised different numbers of simulations.

To begin with the model was used to perform ten independent simulation runs where each run comprised a single simulation. The mean value of each simulation run was calculated. (In this first case the mean value of each run was equal to the actual simulated value because only one simulation was executed within each run.) This was performed for both the Traditional and Design-Build contract strategy options. The model then performed ten independent simulation runs where each run comprised 10 simulations. Therefore the whole process described for the runs comprising single simulations was repeated for runs comprising 10, 100 and 1000 simulations.

Figure 3.15 is a plot of each run's mean project price value against the number of simulations executed in each run. Figure 3.16 is the corresponding plot for project duration. Both figures illustrate that the mean result value becomes more consistent as the number of simulations increases. At 1000 simulations the difference between the 95% confidence limits of the ten mean price values calculated for the Traditional contract strategy is just £10k whereas this measure increases to £30k, £50k and £170k as the simulation number decreases to 100, 10 and finally 1. The project duration results show that if only one simulation is executed it is possible that the Design-Build's mean duration value could exceed that of the Traditional option even though this is highly unexpected (deducible from the results when a greater number of simulations are executed).

It may be inferred from both Figures 3.15 and 3.16 that 100 simulations are sufficient, but since the model running time is negligible, 1000 simulations is the more accurate, and still practical, option. It is important to note that the results and interpretation of the analytical check on the number of simulations are specific to this particular example.

Nonetheless, a conservative estimate appears to be a valid approach. It is equally important to recall the concluding point of the preceding section; apply and interpret the model analysis efficiently.

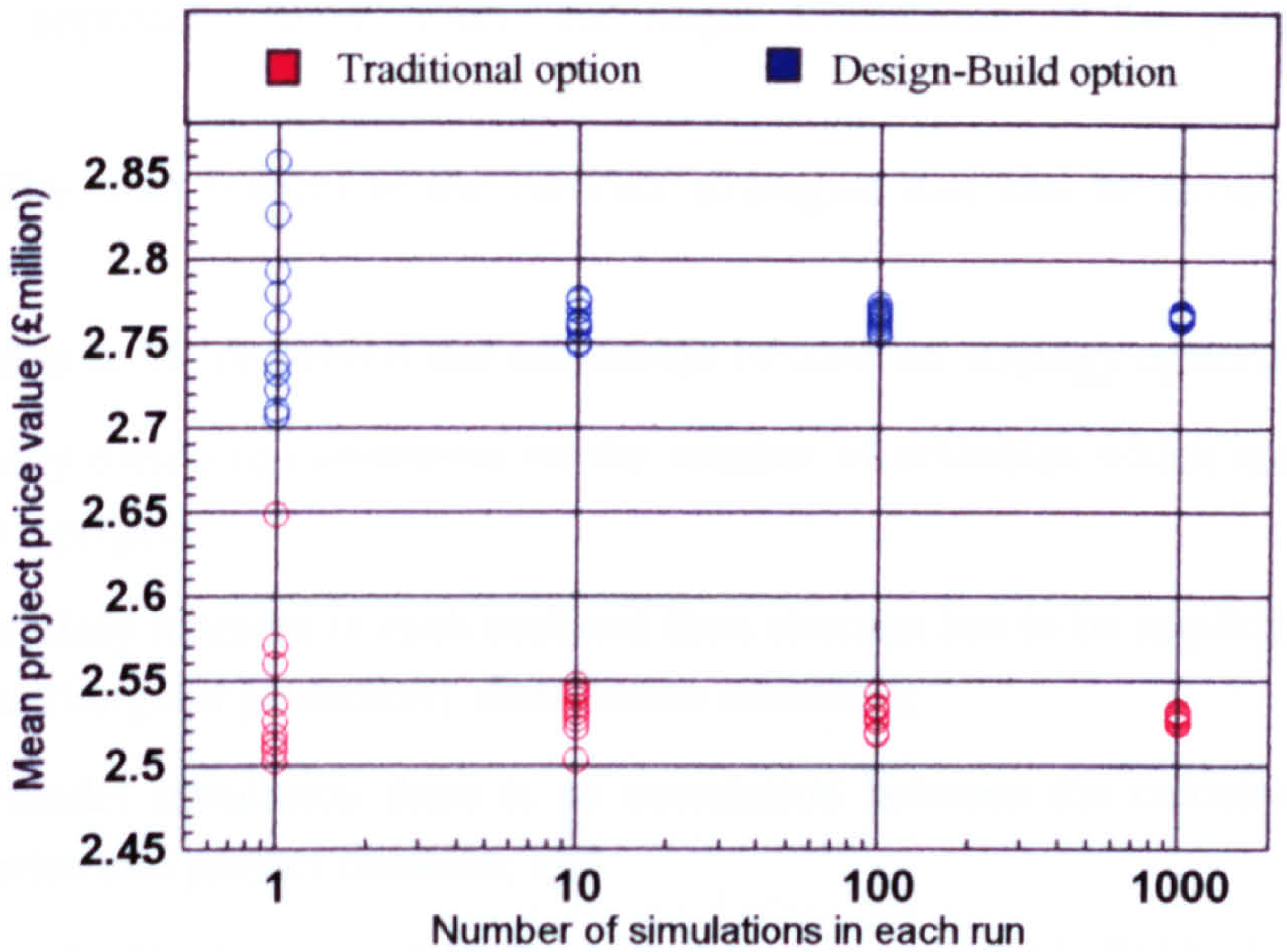


Figure 3.15 Sensitivity of the example project price results to the number of simulation results

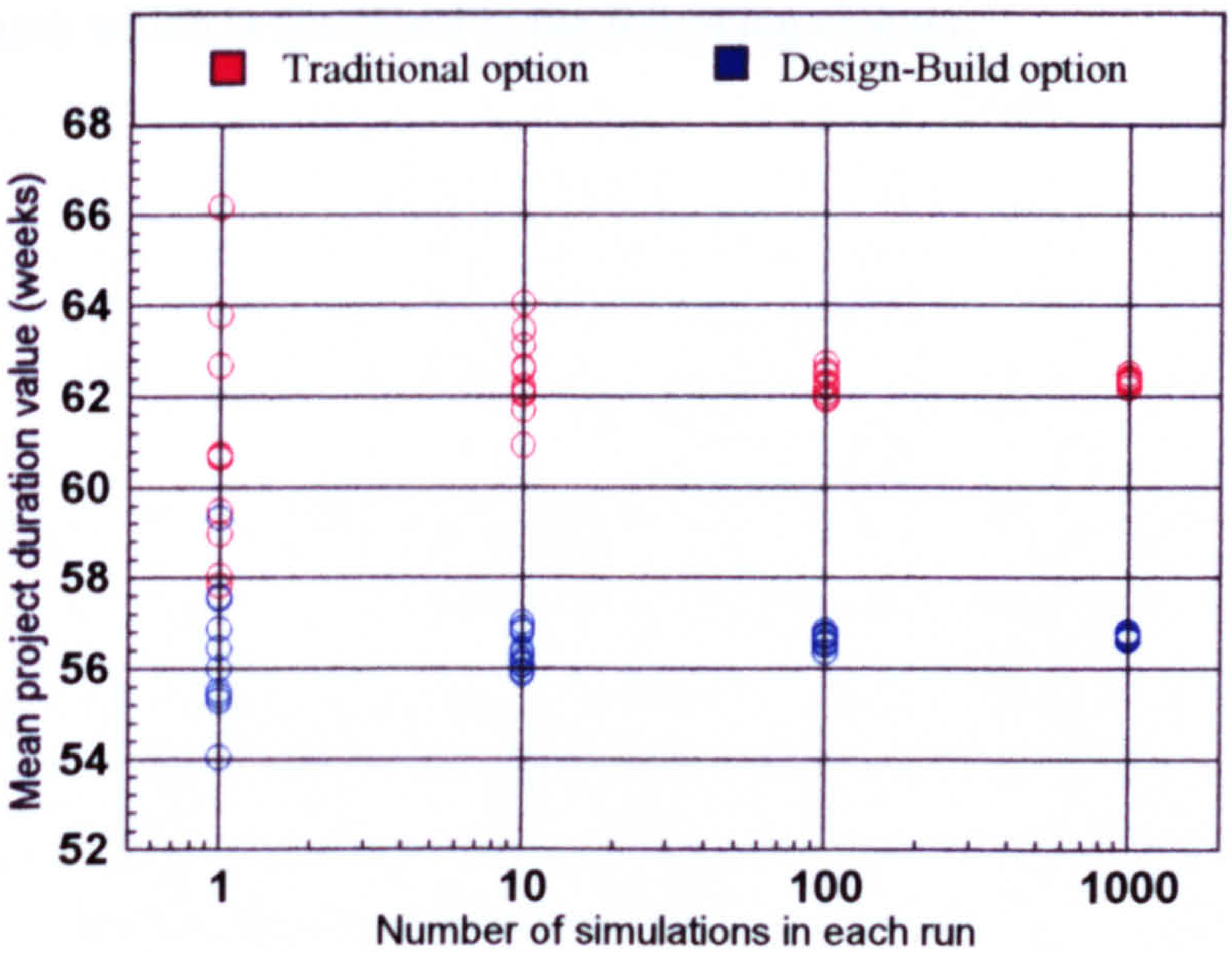


Figure 3.16 Sensitivity of the example project duration results to the number of simulation results

3.3.4 Limitations of the prototype model

It was acknowledged at the outset of section 3.3 that practical constraints were purposely placed upon the model's design. This is because priority was given to the production of a model that enabled testing of the fundamental principles of the quantitative approach. As a result, the major limitations of the prototype model included:

- inflexibility with respect to the contract strategies that can be simulated and thus evaluated;
- imprecision in the definition and simulation of contract strategy options;
- inflexibility owing to constraints on the number of activities which may be used to simulate a project;
- the uncertainty inherent in each cost and time element has to be implicitly accounted for in the triangular probability distribution estimates;
- in each model simulation there is no correlation between the calculated values of project price and project duration; and
- there is no facility to account for dependencies between the individual cost and time elements.

These limitations are described in more detail in Chapter 5 along with refinements that correct these limitations. The refinements derived from ideas that were set aside during the development of the prototype model as well as from insights gained from the empirical research which is described in the following chapter.

4. Survey of industrialist opinion

Up until this point, the research had been based purely upon theory derived from the literature. It appeared that the research would benefit from industrialist opinion and experience about contract strategy selection. Therefore a survey was undertaken to obtain:

- an insight into the conventional approach taken by industrialists to contract strategy selection and to gain an appreciation of the practical constraints related to this decision problem;
- an indication as to whether industrialists perceive the quantitative approach/prototype model is workable and may aid contract strategy selection; and
- sample cost and time data, provided by industrialists, that could be processed by the prototype model for illustrative purposes and to highlight scope for model development.

In order to collect this type of data the survey utilised questionnaires and a loosely-structured interview. Furthermore it was necessary to constrain the survey to a small number of industrialists. Despite its unconventional nature, the survey is referred to, throughout the thesis, as empirical research. The survey did not obtain objective measures of the validity, utility and practicality of the newly-proposed methodology for contract strategy selection. Nonetheless, it provided a meaningful reflection of people's valuable experience.

The constraints imposed by the research subject upon the type of empirical data that could be captured were reflected in the objectives of the survey. These objectives are presented in section 4.1. Section 4.2 describes some of the methodological issues that were considered when the survey was planned. Development of the data collection techniques is described in section 4.3. The results are presented in section 4.4 and a discussion and appraisal of the results appear in section 4.5.

4.1 Objectives of the empirical research

The objectives of the empirical research were to investigate whether industrialists:

- approach contract strategy selection in a manner which concurs with the literature-instigated deduction that numerous deficiencies exist within current practice;
- perceive that different contract strategies are expected to have different cost and time impacts upon a particular project;
- could reflect their subjective assumptions about contract strategies into estimates of their potential impacts upon a project's constituent cost and time elements;
- were able to explicitly account for the uncertainty inherent in their subjective assumptions and quantitative estimates using triangular probability distributions;

- perceived the process, and results, of the application of the quantitative approach aided contract strategy decision-making; and
- could highlight how the quantitative approach could be developed and improved.

In order to establish these objectives it was necessary to acknowledge methodological issues relevant to the research. These issues are discussed in the following section.

4.2 Empirical research methodology

According to Root *et al.* (1997), a methodology is the philosophical approach to research out of which research methods evolve. Research methods are the particular techniques used to collect empirical data (Edum Fotwe *et al.*, 1996).

The traditional, scientific view is that knowledge derives from human experience (the empiricist perspective) or from human reasoning (the rationalist perspective) (Phillips, 1992). It is this traditional view that directs a positivist research methodology.

Positivism is a philosophical concept in which it is assumed that phenomena exist in causal relationships that can be observed, tested and measured (Bilton *et al.*, 1996). Up until the 1960s, sociological researchers increasingly followed their natural science counterparts and adopted comparative positivist methodologies (McNeill, 1990). Although social scientists appreciated the inherent subjectivity in their measurements of the social world they perceived objectivity was attained when the implemented research methods satisfied certain procedural standards (Phillips, 1992). For example, McNeill (1990) acknowledged that data collected within a sociological study was typically perceived to be objective providing:

- the collected data was quantitative because causal correlations could be determined with the use of statistical tests; and
- the researcher did not affect the collected data.

In recent decades the objectivity of all knowledge, and thus positivism, has been disputed (Popper, 1968; Feyerbrand, 1978; amongst others). Not surprisingly, the debate about research methodology has been most intense within the sociological research community. Hughes (1980) referred to Dilthey as one of the first to propound that an improved understanding of human discourse and action would be gained by analysing the meaning, and the origin, of individuals' mental models and not by treating such phenomena as systems of causal relationships. The research methodology supported by Dilthey equates to the concept of interpretivism.

Baker (1994b) reported that the following two issues are very relevant in the development of an empirical research approach:

1. validity (i.e. obtaining a measure of what is intended to be measured); and
2. reliability (i.e. obtaining a consistent measure if the test is repeated).

It would appear that positivists instinctively presume their research methods procure data which satisfy both of the above criteria. In contrast, interpretivists consciously accept a compromise in data reliability by designing research methods that optimise data validity (McNeill, 1990).

Construction management researchers have conventionally tended towards positivism. Edum Fotwe *et al.* (1996) claimed this is a product of the fact that construction management has derived from building and civil engineering which have significant links with the natural and physical sciences. However, in recent years, and particularly while the research reported in this thesis has been undertaken, the traditional positivist approach to construction management research has been challenged (Seymour and Rooke, 1995; Crook *et al.*, 1996; Loosemore *et al.* 1996; amongst others). Consequently, methodological issues related to the empirical research presented in this chapter have received notable attention. The following section identifies and describes these issues.

4.2.1 Methodological issues particular to the research

The second and third chapters described the theoretical development of the quantitative approach to contract strategy evaluation. Empirical research was undertaken to investigate the feasibility and utility of the quantitative approach. However, this empirical study presented a problem from a positivist perspective. It could only be realised by collating the views of practising professionals.

The ideal experiment within the positivist paradigm was simply impractical. This is because it would require a representative sample of industrialists to apply the quantitative approach to at least one actual contract strategy decision problem (ideally all of the industrialists would experience the same decision problem conditions). It was presumed that the industrialists would have to apply the quantitative approach before they could provide an informed judgement about its feasibility and utility.

Despite the impracticality of the ideal positivist experiment, positivism invoked a consideration of a questionnaire survey in which the respondents were presented with the same hypothetical project and were requested to apply the quantitative approach in order to distinguish between the appropriateness of a set of contract strategies for the project in question.

Obviously the intention was to design the questionnaire so that the respondent's task was as straightforward as possible. However, it was considered more important to ensure that the empirical data provided a meaningful indication of the feasibility and utility of the quantitative approach. In order to satisfy this criterion it became apparent that the questionnaire would, inevitably, be demanding for the respondent. Consequently, mail distribution of the questionnaire was quickly ruled out.

Face-to-face interviews was considered to facilitate a more detailed and responsive introduction to the quantitative approach than that which could be included within a questionnaire. Furthermore, this approach provided an opportunity to attain additional empirical data to the questionnaire responses, the quality of which were expected to be impaired given the questionnaire complexity.

The enforced decision to conduct face-to-face interviews was expected to constrain the number of empirical research participants and thus any intention to infer generalisations from the collected data was negated when this decision was made. As a consequence, the research falls short of an ideal positivist experiment. However, the increasingly-voiced argument against positivist methodologies amongst construction management researchers corresponds to a claim that global theories about culture, attitude and motivation are, intrinsically, an over-simplification of complex phenomena (Seymour and Rooke, 1995). The argument is supplemented by the view that data acquired using a positivist approach to construction management research are not particularly meaningful and useful from an industrial perspective (Seymour *et al.*, 1996). This is a significant criterion given that construction management research is particularly 'industry-interactive' (Kumaraswamy *et al.*, 1997).

The critics of positivism have proffered interpretative methodologies as more appropriate for construction management research (Crook *et al.*, 1996; Lenard *et al.*, 1997; Rooke, 1997; amongst others). A variety of qualitative research methods have evolved out of the interpretative paradigm. Tesch (1991) categorised qualitative research methods into the following:

1. Language based; investigate the source, meaning and significance of the language related to the subject.
2. Descriptive; obtain a coherent and comprehensive account of the respondents' perspective about the subject.
3. Theory development; construct theories from the collected data rather than prior to data collection.

It was acknowledged that an application of language-based research methods from the interpretative perspective would certainly have produced relevant insights. This is because the concept of the quantitative approach to contract strategy evaluation developed from a literature-instigated deduction that numerous deficiencies are inherent in contract strategy selection practice. However, contract strategy selection is a very complex and case-specific decision problem (see sections 2.1. and 2.2). Therefore an investigation into industrialists' understanding of the whole decision problem on a general basis was perceived to present a very demanding task. Firstly, this approach was considered to be beyond the capabilities of a relatively novice researcher. Secondly, and more importantly, the potential scope of subject material in the collected data appeared so immense that it was judged likely to dilute the primary objective of the study (i.e. test the feasibility and utility of the quantitative approach).

In order to satisfy the research objectives and the practical constraints of the research, it was decided to use face-to-face interviews and questionnaire research techniques to attain a coherent and explicit review of the quantitative approach. This approach corresponds, essentially, to the second type of qualitative research method identified by Tesch (1991) (see previous page).

A feasibility study was undertaken to obtain industrialists' views about the subject of contract strategy selection and assess how to refine the empirical research strategy. The feasibility study is reported in section 4.3.2, but it is necessary at this point to highlight a very significant insight gained from the study. It confirmed the suspicion that the industrialists would have difficulties in understanding what was entailed in the quantitative approach to contract strategy evaluation.

Cannel and Kahn (1968) claimed the following three conditions as crucial to the execution of successful interviews:

- accessibility; the respondent's ability to obtain the required information
- cognition; the respondent's understanding of what is required of him/her
- motivation; the respondent's willingness to provide the required information

Given the results of the feasibility study, the second of these conditions, cognition, became a major objective in the development of the research methods. It was decided to design a fairly flexible and informal interview structure and also to present the empirical research participants with a significant amount of information about the quantitative approach. The research methods and their design process are described in detail in subsequent sections.

A conscious decision was made to adopt a research methodology that was a departure from the conventional positivist approach. Although the extreme interpretivist perspective was not adopted, the reasons for its increasing popularity, within construction management research, provided considerable guidance. For instance, in order to optimise the validity and utility of the empirical data, a compromise in reliability was made. Harvey and MacDonald (1993) surmised that nothing is gained if the collected empirical data is invalid. Furthermore, Gunning (1994) and Buchanan *et al.* (1988) insisted that a researcher should not be oppressed by traditional approaches to research.

It has also been reported that the adopted research methodology and methods were notably dictated by the research subject. The process of testing a contract strategy decision-aid presents a very difficult and unanswerable problem. However, this does not mean that the subject should not be researched. On the contrary, the unconventional nature of the empirical research methodology is a reflection of the complexity of contract strategy selection which, in turn, is a reflection of its importance (see section 2.2.1). McNeill (1990), with reference to sociological research, said that "...we must not dismiss experiments in social science. They may not give final answers, but can provide some very important insights".

A controlled and systematic approach was adopted when the empirical research was planned and executed. However, within this approach, pragmatism and opportunism were required to design the empirical research methods and establish the study's objectives.

4.3 Empirical research methods

The purpose of the empirical research was to investigate the feasibility and utility of the quantitative approach to contract strategy evaluation. It has already been acknowledged that the ideal means of testing the quantitative approach would have been to observe experienced contract strategists as they applied the approach at the outset of actual projects. For practical reasons this was not possible. However, it was perceived possible to design a questionnaire which simulated a contract strategy selection scenario at the outset of a project.

Section 4.3.1 outlines the general requirements for effective questionnaire design and describes the initial questionnaire (referred to as Questionnaire 1A). The questionnaire was shown to industrialists during a stage which is referred to as the empirical research feasibility study. During this period, discussions were held with seven construction-related organisations. Section 4.3.2 reports the crucial insights provided by the study and justifies the subsequent decisions made about the empirical research methods.

Section 4.3.3 describes the questionnaire re-design process and presents the resultant questionnaire (referred to as Questionnaire 1B). The issues that were addressed in the design of a face-to-face interview structure are summarised in section 4.3.4.

Finally, section 4.3.5 reports the result of a decision to alter an aspect of the empirical research approach whilst the study was in progress. Owing to a poor response rate to Questionnaire 1B, a new questionnaire (referred to as Questionnaire 2) was designed with the intention to avert the intrinsic limitations of Questionnaire 1B.

4.3.1 Description of the initial questionnaire and its design concept

The questionnaire described in this section was labelled Questionnaire 1A. A copy of the questionnaire is provided in Appendix A.

The questionnaire aimed to simulate a contract strategy decision scenario at the outset of a particular project. Therefore the questionnaire had to provide information about the circumstances of the particular decision problem. Obviously constraints had to be placed upon the amount of information that could be included in a questionnaire. As a result, the descriptions of the project circumstances and the contract strategy options were not comprehensive.

The description of the project circumstances included reference to the project's size, type, status, site conditions, locality and complexity. Section 2.2.4 provided some indication that contract strategy evaluation typically addresses factors of this type. Figure 4.1 presents the project description featured in Questionnaire 1A.

In order to investigate whether consistencies existed between the questionnaire responses, the questionnaires prompted the respondent to evaluate a particular set of contract strategy options. Again it was impractical to include an exhaustive description of each contract strategy in the questionnaire. Therefore each option's description included reference to:

1. commonly perceived arrangements associated with particular labels (e.g. Traditional); and
2. broad details of the contract between the client and the contractor responsible for the project's construction (i.e. referred to as the contract between the client and principal contractor in Chapter 3)

> The project is a large factory building with offices. The overall project cost is estimated at £15 million and project duration at 5 years. The building will occupy approximately 20,000 square metres. The building requires an original design because it is a one-off project.
>
> The building will house some specialised equipment. The building's structure will be complex and will comprise different structures. It is unlikely that the construction process will need to employ any new technology. The building's steel frame will be prefabricated locally and transported to the site for erection.
>
> The site is currently occupied by disused warehouses. Therefore the construction contract includes demolition of these buildings and clearing of the site. The soil is relatively strong and ground problems are unlikely.
>
> The site is located on the outskirts of a city centre. The adjacent buildings could impose some construction restrictions. Physical access onto the site is easy, but traffic congestion on the surrounding road infrastructure is not uncommon.

Figure 4.1 The project description featured in Questionnaire 1A

The questionnaire presented four different contract strategy options:

- **Traditional:** The client appoints an organisation to undertake the design. The design is completed before obtaining tenders by means of a **competitive one-stage** process. A **full bill of quantities** will be the basis of the tender, although the firm price agreed at the tender stage will be subject to **re-measurement**. The appointed contractor is to be an independent organisation from that of the client and designer.
- **Accelerated Traditional:** As with the Traditional option, the client appoints an organisation to undertake the design and the appointed contractor is to be an independent organisation from that of the client and designer. The construction contractor is appointed, before design completion, following a **negotiated** tender which is based upon **outline drawings and a detailed project**

specification. The contractor is to reimbursed for the actual construction costs and also receives a fixed fee agreed at the tender stage (i.e. cost plus fixed fee type pricing mechanism).

- Management Contracting: The client appoints an organisation to undertake the design. During the early design stages, another organisation is appointed to act as a management contractor. This appointment follows a pre-qualification process and negotiation of a management fee which is quoted as a percentage of the construction cost. The construction work is divided into five packages. Tenders are obtained for each work package by means of single-stage selective tendering. Tenders are based upon drawings and approximate quantities. The works contractors are to be reimbursed using cost plus percentage fee type pricing mechanisms.

- Design-Build: The entire design and construction work is let to a single organisation following a two-stage tender process. First stage tenders, based upon a detailed project specification, lead to a shortlist of, no more than, two contractors. At the second stage the contractor is selected on the basis of the design proposals and a fixed lump sum price.

The remainder of the questionnaire comprised four sections.

Section 1 Separated Design and Construction

The questionnaire presents the minimum, most likely and maximum values of:

- design cost;
- design time;
- construction cost;
- construction time.

The estimates were based upon the assumption that the project was to be procured using the Traditional option.

The questionnaire prompts the respondent to estimate corresponding values assuming that the project is to be procured using, firstly, the Accelerated Traditional option and, secondly, the Management Contracting option (all costs incurred by the client).

Section 2 Integrated Design and Construction

Section 2 was specifically designed for the evaluation of the Design-Build type contract strategy. The design and construction cost and time estimates for the Traditional contract strategy are summed. The questionnaire provides both total cost and total duration estimates in terms of their minimum, most likely and maximum values. The respondent is prompted to estimate the corresponding total values based upon the assumption that the project is to be procured using the Design-Build option.

Section 3 Design-Construction Overlap

The respondent is requested to estimated the length of time between the start of the design until the start of construction (i.e. design-construction overlap) for each of the three contract strategy options other than the Traditional arrangement. Unlike the other sections, this time element is to be estimated as a single value for each contract strategy.

Section 4 Tender Process Cost/Duration and Transaction Costs

For all four contract strategies the questionnaire prompts the respondent to estimate a minimum, most likely and maximum value of the tender process costs, tender process duration and the transaction costs (all costs incurred by the client). Unlike Sections 1 and 2, it was decided not to include estimates for the Traditional option.

In the case of the Management Contracting option, the respondent is requested to estimate the tender costs associated with the management contractor's appointment in addition to the cost and duration of the entire tender activity in which works contractors are appointed.

The questionnaire was subsequently revised. This is explained in Section 4.3.3. Owing to the modifications this initial questionnaire was labelled Questionnaire 1A. A copy of Questionnaire 1A is included in Appendix A.

Although the questionnaire did not precisely simulate a contract strategy decision scenario at the outset of a project, its concept nonetheless had the potential to demonstrate whether industrialists:

- perceive that different contract strategies are expected to have different cost and time impacts upon a particular project;
- could reflect their subjective assumptions about contract strategies into estimates of their potential impacts upon a project's constituent cost and time elements;
- were able to express their estimates as triangular probability distributions; and
- held consistent views about general contract strategies' expectant cost and time impacts on projects.

Therefore it was perceived that the questionnaire concept would provide a meaningful indication as to whether the quantitative approach to contract strategy evaluation was feasible and useful.

4.3.2 Empirical research feasibility study

The feasibility study aimed to provide the industrialists with an opportunity to express their own views on the subject of the research and investigate how the empirical research methods could be optimised. Given these aims it was decided to conduct the feasibility study using fairly informal face-to-face or telephone interviews.

During March 1997, twenty three industrialists were informed, via mail, about the research subject and also about the fact that the research was an investigation into a new approach to contract strategy selection. They were asked whether they would be prepared to discuss these issues.

Seven industrialists agreed to participate in the feasibility study (i.e. a response rate of 30%). Five of the industrialists agreed to a face-to-face interview, while the other two were interviewed over the telephone. The interviews took place between April 9th and May 13th 1997. Each industrialist is referred to individually by a label to maintain their anonymity. The label and profession of each of the seven industrialists interviewed is shown in Table 4.1.

The five industrialists that were interviewed face-to-face were shown a copy of Questionnaire 1A during the interview and asked to give their opinion about its design and information requirements. Meanwhile all of the interviews comprised a flexible framework of questions, including:

- Which types of contract strategy do you normally deal with? Are there any other, less familiar types of contract strategy that you have had experienced of?
- Do you consider that the suitability of a contract strategy is dependent upon a project's circumstances?
- How would you normally evaluate the suitability of a contract strategy to a project's circumstances?
- What types of criteria typically rule the suitability of a contract strategy?
- Do you think that these criteria can be reduced to the client's price, time and quality objectives for the project?
- Do you consider that each client prioritises their price, time and quality objectives for the project?
- Do you think the contract strategy used on a project affects the project's price, duration and quality?
- Do you consider that each type of contract strategy has a different likelihood of enabling the achievement of the client's price, time and quality objectives?
- When you are selecting the contract strategy for a project do you make assumptions about the effect that a contract strategy is likely to have on the project's price, time and quality?
- On a specific project, could you use these assumptions to estimate, in terms of pounds and weeks, the cost and time that certain contract strategies were likely to save relative to other contract strategies?

Label	Interview Type	Profession
P1	Face-to face	Design consultant/Project manager
P2	Face-to face	Quantity surveyor/Project manager
P3	Face-to face	Design consultant/Project manager
P4	Face-to face	Quantity surveyor/Project manager
P5	Face-to face	Quantity surveyor/Project manager
P6	Telephone	Quantity surveyor/Project manager
P7	Telephone	Quantity surveyor/Project manager

Table 4.1 Participants in the feasibility study

Four of the industrialists (P2, P3, P4 ad P5) agreed to be interviewed again in greater depth. Hence their responses with regards to their current approach to contract strategy evaluation and their initial reactions to the quantitative approach are included in section 4.4.2. The other three industrialists (P1, P6 and P7) preferred not to be interviewed again. P1 rejected the quantitative approach outright. Meanwhile P6 and P7 reasoned that they had insufficient time available. Both P6 and P7 expressed reservations about the feasibility of the quantitative approach, but P7 supported the idea of undertaking a more structured and transparent evaluation of contract strategies.

The feasibility study provided particularly useful information about the empirical research strategy. Foremost, all seven industrialists experienced difficulties in understanding the quantitative approach. Therefore it was presumed that, in order to obtain empirical data of sufficient quality, the industrialists had to be introduced to the quantitative approach gradually. In addition, they must be given the opportunity to ask their own questions about the approach. Therefore it appeared that face-to-face interviews, as opposed to mail surveys and telephone interviews, had to be undertaken. Furthermore it was evident that the interviews had to adopt a fairly flexible structure in order to obtain informed views from the industrialists. A description of the interview structure is provided in Section 4.3.4.

Four of the five industrialists who were interviewed face-to-face in the feasibility study were shown a copy of Questionnaire 1A. Their reactions are summarised below:

- all four industrialists commented that the questionnaire appeared to require a lot of time and effort to both read and complete;
- some of the industrialists required a more a detailed definition of 'transaction costs' than that featured in the questionnaire;
- some of the industrialists were a little confused as to whose costs were to be estimated;

- two of the industrialists perceived that the hypothetical project description presented in the questionnaire was not sufficient to enable a realistic contract strategy evaluation process to be undertaken. One of the industrialists claimed that the project description needed to include information about the client and outline details of the design.

The four industrialists' views about Questionnaire 1A were somewhat conflicting. All four considered the questionnaire was too demanding, whilst two of these industrialists added that the description of the hypothetical project scenario needed to be extended. However, it was perceived that both these problems could be reduced if the questionnaire was completed during, or after, a face-to-face interview. In other words, it appeared that the interviews could be used not only to introduce the quantitative approach and attain industrialists' reactions to the approach, but also to explain the questionnaire.

It was also recognised that if the questionnaires were completed during face-to-face interviews there was an opportunity to obtain the industrialists' reasoning for their cost and time estimates. This would provide further insights into the industrialists' views about contract strategies and provide an indication as to whether consistencies existed between their views.

The industrialists' reactions to the questionnaire and the decision to explain the questionnaires during face-to-face interviews led to a re-design of the questionnaire. The questionnaire modifications are described in the following section, whilst the structure of the main interviews is described in section 4.3.4.

4.3.3 Re-design of the questionnaire

The questionnaire described in this section was labelled Questionnaire 1B. A copy of the questionnaire is provided in Appendix A.

Although it was decided to conduct face-to-face interviews, it was considered appropriate to enclose a copy of the questionnaire with the letter that requested industrialists' participation in the research. Since all seven industrialists who participated in the feasibility study experienced some difficulty in understanding the quantitative approach, the questionnaires appeared a to be a means of both introducing the quantitative approach and outlining the type of information which the study required. As a consequence it was decided to include a thorough and prominent introduction and description of the respondent's tasks in the questionnaire.

During the feasibility study one of the industrialists suggested that the project circumstances description ought to include information about the client and conceptual design. This suggestion was incorporated into the questionnaire re-design. However, it was considered that the factory building which featured in Questionnaire 1A was not the ideal project if the questionnaire was to present design details. It appeared that a more standardised building project would restrict the amount of design detail to a reasonable level. Therefore it was decided to change the project from the factory building to a seven-storey reinforced concrete-framed office building in which the floors were effectively uniform. Figure 4.2 shows the introductory information about the project that is presented within the questionnaire.

Project scenario:

A relatively new insurance company wishes to build a new headquarters. The company has had very little construction experience and has no in-house resources to assist in administering the project. The company is deciding whether or not to build on a prospective site. The company has employed a team of consultants to perform a feasibility study for a fee of £15,000. The study included an investigation of the ground and site characteristics and some preliminary design was undertaken. The main items of the feasibility report are summarised below.

Project description:

The project is a 7-storey reinforced concrete framed office block which will provide a gross floor area of 10,000m^2 (9000m^2 of office space). The building must provide office space for 1300 people. The overall project cost is estimated at £8 million and project duration of 21 months.

The soils on the site are mainly clay with some sand mixed in. The soil is relatively strong and its bearing capacity is estimated at 200kN/m^2.

The site was previously occupied by a cinema which has since been demolished and cleared. The site is located on the outskirts of a city centre. The adjacent buildings could impose some construction restrictions and traffic congestion on the surrounding road infrastructure is not uncommon (see **Site Plan** on page 2).

The main aspects of the preliminary design are outlined in Table 1 and the sketches on page 2.

Figure 4.2 Introductory information about the hypothetical project presented within Questionnaire 1B

Given that Questionnaire 1B would provide design details, there appeared scope to request the respondent to estimate more specific cost and time elements than those which feature in Questionnaire 1A (i.e. break the evaluation process down further). Therefore, whereas Questionnaire 1A deals with the overall construction price and duration, it was decided to separate the construction activity into a series of activities. It was acknowledged that the Building Cost Information Service separate construction into the following six activities:

1. substructure
2. superstructure
3. internal finishes
4. fittings

5. services; and
6. external works

In order to avoid placing excessive demands upon the respondent, the third, fourth and fifth activities in the above list were grouped together. Therefore Questionnaire 1B divided construction into four activities. It was noted in section 3.3.2.2 that the development of the empirical research strategy coincided with the development of the model that facilitated the application of a quantitative approach to contract strategy evaluation. The decision to use four activities to represent the construction process of the project governed the model design decision to permit the user to specify up to four construction activities.

The respondent was prompted to estimate the cost of each activity as the cost to the contractor rather than the cost to the client. The construction price was to be calculated using each contract strategy's corresponding pricing mechanism formula once the respondent had estimated the values of the relevant tender bid parameters (see section 3.3.2.3.1.1).

It should be noted that the questionnaire describes a simplified pricing mechanism, within the Traditional contract strategy, than that simulated by the prototype model. The model simulates quite an elaborate Guaranteed Maximum Price system which involves a Target cost and a Target fee (see section 3.3.2.3.1.1). However, to reduce the number of estimates required from the respondent, it was decided to reduce this pricing mechanism type to a system in which there is no Target fee and the Guaranteed Maximum Price equates to Target cost in the respective pricing mechanism formula.

It was considered that the modifications to the respondent's tasks in Questionnaire 1B would provide a better demonstration of whether the industrialists were able to discern which particular aspects of a project's performance were expected to be affected by contract strategies. This appeared to justify the fact that the revised questionnaire requested more information from the respondent than Questionnaire 1A. In addition, it was perceived that the decision to complete the questionnaires during, or after, face-to-face interviews would increase the efficiency with which the questionnaires could be completed. A concession was, however, necessary to reduce the number of contract strategies, which the respondent is asked to evaluate, to three from the four which appear in Questionnaire 1A. The 'Accelerated Traditional' type contract strategy was excluded from Questionnaire 1B and the descriptions of the other three contract strategies were slightly altered to the following:

1. **Traditional:** a team of design consultants complete the design and administer the project. The design is complete before the construction is let to a general contractor using a negotiated tender process. The client's detailed bill of quantities is used to negotiate a Guaranteed Maximum Price (any cost savings are shared equally) and it also provides a basis for re-measurement of the price.

2. **Design-Build:** the remainder of the design and the entire construction work is let as a single package using a competitive one-stage tender process. The package is let on the basis of a fixed lump sum price.

3. **Management Contract:** a management contractor is appointed during the conceptual design stage following a pre-qualification process and negotiation of the management contractor's fees. The pre-construction fee is a lump sum, while the fee for services during construction is based on a target cost arrangement where the management contractor receives a percentage value of the construction cost, but any cost savings or overruns relative to a negotiated target cost are shared equally between the client and management contractor. The management contractor divides the construction into work packages and each package is tendered competitively on the basis of a cost plus percentage fee payment mechanism. The management contractor administers the tender process for each work package.

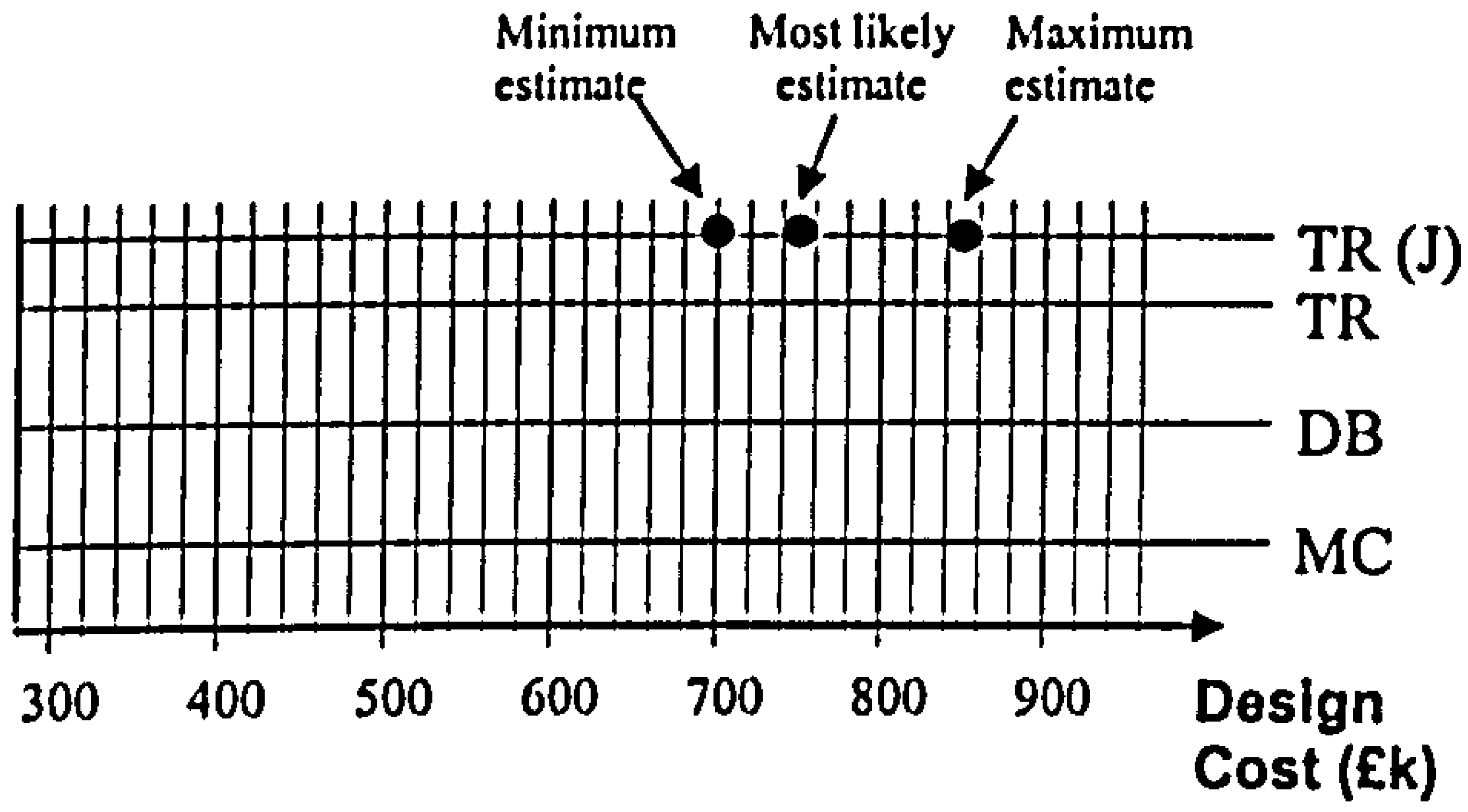
Similarly to the system used in the original questionnaire, Questionnaire 1B provides the various cost and time elements' minimum, most likely and maximum estimated values which are based upon the assumption that the project is to be procured using the Traditional type contract strategy. The respondent is requested to estimate new values for the two contract strategy alternatives to the Traditional option. In addition, Questionnaire 1B describes the estimates provided for the Traditional option as those made by a junior estimator and therefore permits the respondent to alter the estimates provided for the Traditional option.

Questionnaire 1B featured a specifically-designed system for the respondent to record his/her estimates. It was designed to assist the respondent to cross-reference the estimates, for each cost and time element, between the three contract strategy alternatives. A description of the system was included within Questionnaire 1B including a demonstration using 'design cost' as the example cost element. The demonstration is shown in Figure 4.3.

Another significant adjustment to the questionnaire was the respondent's task to estimate a project schedule for each of the three contract strategy options. The schedule was to include the six project activities for which the respondent had previously estimated the cost and duration.

A copy of Questionnaire 1B is provided in Appendix A.

An example of the type of chart on which you must display your estimates for each cost and time element



KEY

TR (J)	Junior estimator's Design cost estimates for the Traditional contract strategy
TR	Design cost estimates for the **Traditional** contract strategy
DB	Design cost estimates for the **Design-Build** contract strategy
MC	Design cost estimates for the **Management Contracting** contract strategy

The above chart has a cost scale. The 3 black marks on the chart use the cost scale to represent the junior estimator's minimum, most likely and maximum estimates of the **Design cost.**
These black marks lie along the horizontal line labelled TR(J) which in the KEY is defined as the junior estimator's estimates for the **Traditional** contract strategy.

In this example you would be asked to complete the chart by:

1. Displaying your minimum, most likely and maximum **Design cost** estimates for the **Traditional** contract strategy on the horizontal line labelled TR (if you consider the junior estimator's estimates for the **Traditional** contract strategy are incorrect).
2. Displaying your minimum, most likely and maximum **Design cost** estimates for the **Design-Build** contract strategy on the horizontal line labelled DB.
3. Displaying your minimum, most likely and maximum **Design cost** estimates for the **Management Contracting** contract strategy on the horizontal line labelled MC.

The example chart completed

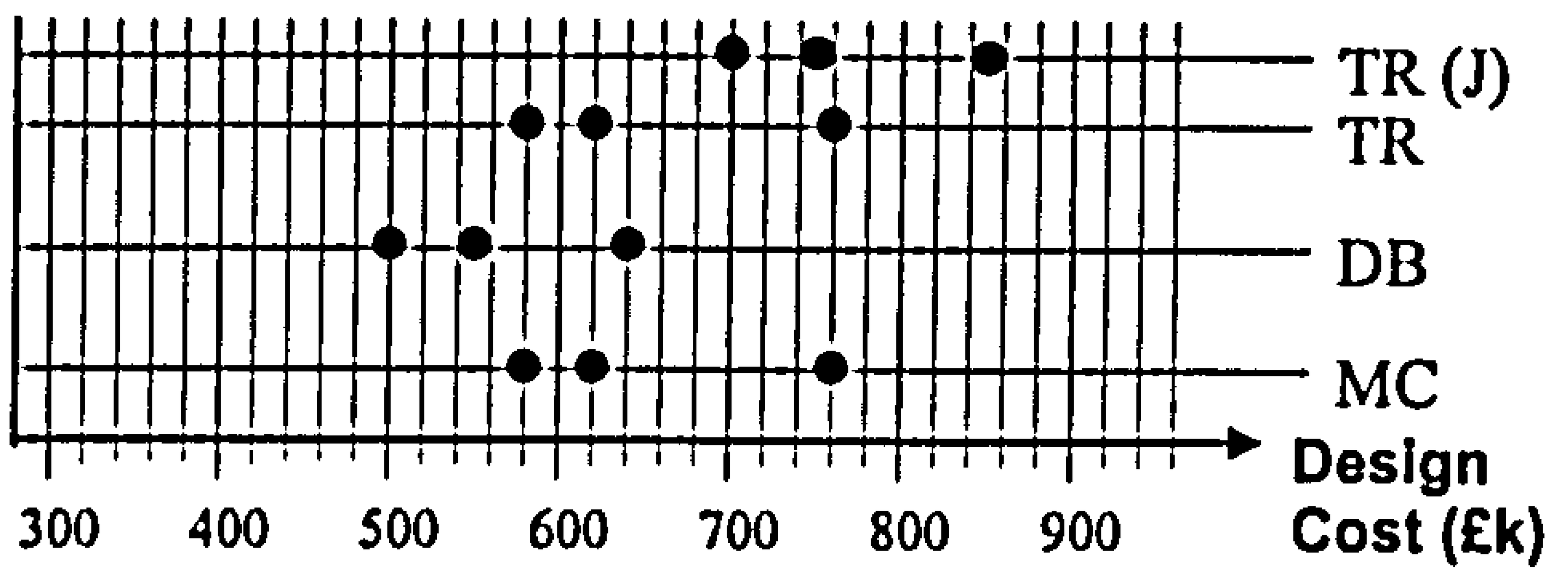


Figure 4.3 An example of the system used in Questionnaire 1B for the respondent to record his/her estimates

4.3.4 Design of the interview structure

It has already been established (section 4.2.1) that the decision to use face-to-face interviews was necessary to ensure that the empirical research participants thoroughly understood the quantitative approach as well as to assist them in the completion of the questionnaire. In addition, it was decided to adopt a fairly informal and flexible interview structure. It was appreciated that this interview type exposed the collected data to a greater risk of bias effects induced by the interviewer than a highly structured interview. However, Robson and Foster (1989) acknowledged that flexible and informal interviews are likely to obtain a more accurate account of the respondent's opinion about a subject where the subject is particularly complex.

In accordance with the interview types described by Moser and Kalton (1971), the result of the interview design process equated to a 'guided' interview. The method allows the interviewee to respond to questions in their own terms, but there are pre-established topics which the interview must cover. The topics are referred to herein as 'Question Areas'.

The question areas began with an introduction. The introductions were brief, but fairly detailed explanations about an aspect of the quantitative approach which was the subject of the ensuing questions. The explanations, along with the accompanying visual aids, were designed prior to the interviews. Although key questions within each question area were also designed, it was anticipated that improvised probing during the interviews would be required to support the key questions.

It was recognised that the explanation preceding the questions within each question area and the fairly flexible interview structure would generate a rapport between the interviewer and interviewee. Buchanan *et al.* (1988) reported that the interviewee must be satisfied in the sense that:

1. they understand the aims of the study and feel they can contribute to it; and
2. they perceive the interviewer is trustworthy and genuinely wants to listen.

It proved to be extremely difficult to obtain empirical research participants. The industrialists who refused to participate in the research often made reference to the reason that they were unable, or not prepared, to disclose information about their organisation's contract strategy selection policies. The problem of confidentiality was also evident when two of the participants in the feasibility study insisted that the interview was not tape recorded. During the feasibility study, it was observed that an interviewee was noticeably more open where even the suggestion of tape recording was not raised. Moser and Kalton (1971) suggested that tape recording interviews can hinder the response rate and data validity. Therefore it was decided to rely upon note-taking during and after each interview. In addition to the above reasons behind this decision, it was also considered to be a reasonable concession given the pragmatism underlying the empirical study's objectives.

4.3.4.1 The aim, subject and sequencing of the question areas

Miles and Huberman (1994) reported that research questions readily formulate from the conceptual framework of the research hypothesis. Therefore it was inferred that the interview questions should directly relate to the principles of the quantitative approach to contract strategy evaluation and also to the reasons that led to the development of the approach.

The motivation to research into the subject of contract strategy selection was instigated by the deduction, from relevant literature, that current practice was typically defective (see section 2.3.2). It was therefore imperative to question industrialists about their current approach to contract strategy selection. This area of questioning was intuitively considered to provide an appropriate opening to the interview (i.e. Question Area 1). The decision was supported by Patton (1990) who reported that a question that prompts a descriptive response at the interview outset can ease the interview atmosphere. Furthermore, Patton (1990) recognised that this question type can assist the interviewee to establish a context which therefore may be used by the interviewee as a base against which his/her subsequently elicited opinions could be contrasted. Therefore more accurate and meaningful responses are gained.

Following a description of the quantitative approach, the interviewee was asked to give their initial reaction to its feasibility (Question Area 2). The decision to ask for a holistic reaction at the outset was based upon a suggestion by Miles and Huberman (1994). They claimed that clarity and specificity were promoted by the use of major general questions each of which are followed up with subquestions. The technique where issues are introduced by a general question and pursued by more detailed questions was defined by Fellows and Lui (1997) as 'funnelling'. Therefore the question areas that followed Question Area 2 were related to specific principles of the quantitative approach. The principles and the questions areas in which the principles feature are listed in Table 4.2.

Question Area 3 requests the respondents to give their opinions about the general concept of systematically evaluating contract strategies in terms of a project's constituent cost and time elements. Although Question Area 4 repeats this inquiry, it requires the respondent to consider the concept applied to four different examples. Patton (1990), who refers to this technique as simulation questioning, suggested that a line of questioning may be more profitable if the interviewee is provided with a context within which to respond.

It was not until after the interviews had begun when it was realised that diplomacy was particularly required when the interviewee was questioned about triangular probability distributions (i.e. Question Area 5). Very few of the industrialists appeared familiar with probabilistic techniques and, despite the explanation provided during the interview, the majority of industrialists were seemingly uncomfortable with answering questions on the subject. Moser and Kalton (1971) acknowledged that over-probing about a knowledge type question, when the interviewee's knowledge on the respective subject is limited, can have a significant effect upon the interviewee's motivation to co-operate further. Therefore this advice was subsequently heeded for Question Area 5.

Principle of the quantitative approach	Question Area(s) in which the corresponding principle is the question subject
Structured breakdown of contract strategy evaluation	Q.A.3
Explicit evaluation of contract strategies in terms of cost and time at a project's outset	Q.A.3, Q.A.4, Q.A.5
Explicit account of the uncertainty inherent in contract strategy evaluation	Q.A.5
Explicit, quantitative results of contract strategy evaluation	Q.A.7
Setting clear, realistic and balanced price and duration objectives	Q.A.7
Capacity to make better contract strategy decision and gain an improved understanding of contract strategy selection from application of the quantitative approach	Q.A.8

Table 4.2 The principles of the quantitative approach that were the subjects of the interview questions

Question Area 6 involves an explanation of the questionnaire (Questionnaire 1B and, later, Questionnaire 2) together with an inquiry as to whether the interviewee would be prepared to complete a questionnaire. It is perhaps useful to note at this point that the questionnaire aimed to investigate the following principles of the quantitative approach:

- translation of subjective assumptions about contract strategies into cost and time estimates (albeit not at the outset of a real project);
- explicit reasoning behind the subjective assumptions and quantitative estimates;
- flexibility to evaluate contract strategies with respect to the most relevant issues; and
- explicit account of the uncertainty inherent in contract strategy evaluation.

The same principle behind Question Area 4 underlies Question Area 7. The interviewee is presented with an example set of results calculated from an application of the quantitative approach and is subsequently questioned about the utility of the results and again about the feasibility of the process involved in obtaining results of this type. Therefore the example results provided the interviewee with a context which may be addressed in the response.

Since Question Area 8 concerned the long-term effects of the quantitative approach applied to contract strategy selection, this appeared a suitable issue on which to conclude the interview. Although it was acknowledged that this issue was somewhat abstract, it was perceived that the responses could indicate, firstly, whether the interviewee had understood the quantitative approach, and secondly, which particular aspects of the quantitative approach were perceived to aid the decision process.

It could be argued that the context of the question areas highlight only the advantages of the proposed quantitative approach and thereby bias the interviewee. However, it was inferred that a contributory factor to the low response rate as well as to the negative responses received during the feasibility study was because the quantitative approach was intended to change the industrialists' current practice. Chapman and Ward (1997), with regards to institutionalising risk management within organisations, recognised the following reasons for resistance to such change:

1. parochial self-interest in maintaining the status quo;
2. inability to perceive a need for change;
3. pressure of other work;
4. concern about the costs of introducing new procedures;
5. individuals concerned that they will be unable to carry out the new procedures;
6. uncertainty and suspicion about the nature of the change.

The interview structure aimed to ensure that the interviewed industrialists explicitly and rationally considered:

- the degree of discipline within their current approach to contract strategy evaluation;
- how their approach could become more disciplined; and
- the potential advantages of a more disciplined approach.

It was perceived that the subtle promotion of the quantitative approach would counterbalance the interviewees' innate resistance.

4.3.5 Design of the second questionnaire

The questionnaire described in this section was labelled Questionnaire 2. A copy of the questionnaire is provided in Appendix A.

Section 4.4.1 reports that from the fifty industrialists sent Questionnaire 1B only two completed it (i.e. response rate of 4%). The excessive demands of Questionnaire 1B were cited amongst the reasons for non-responses. In addition to the sizeable amount of information requested by Questionnaire 1B, it was also appreciated that the difficulty of the tasks was compounded by the questionnaire's inability to accurately simulate a contract strategy selection scenario. This is because only a limited description of the project circumstances and contract strategy options could be included in the questionnaire.

During these early interviews, including those regarded as the feasibility study, it was observed that the industrialists occasionally made reference to projects that they had previously been involved in. For example, they recalled instances where a contract strategy-related decision could have, or did, lead to cost and time savings.

It was deduced that the constraints upon the decision scenario description in Questionnaire 1B would be avoided if instead the respondent was asked to relive an actual decision scenario. The respondent would be able to recall all of the relevant details about the chosen project's circumstances. It was acknowledged that the respondent would be inclined to call upon details which were unavailable at the project's outset. Therefore an industrialist's application of the quantitative approach to a past project would be susceptible to numerous biases. However, owing to the difficulties associated with simulating an actual contract strategy decision problem and because Questionnaire 1B generated a very low response rate, it was decided to design a second questionnaire which prompted the respondent to apply the quantitative approach to a project that they had previously been involved in. A copy of the resultant questionnaire, referred to as Questionnaire 2, is presented in Appendix A.

In Questionnaire 2 the respondent is required to specify details about the project and client and then make a series of cost and time estimates for at least two contract strategies. The questionnaire requests the respondent to estimate fewer cost and time elements than Questionnaire 1B because it groups the four construction activities featured in Questionnaire 1B into a single activity.

In order to negate the problem of imperfect descriptions of the contract strategy options, the respondent in Questionnaire 2 is able to evaluate any contract strategies. Therefore the respondent is able to fully appreciate and account for the finest details of each option evaluated.

It was expected that one of the contract strategies that is evaluated would be the actual contract strategy used to procure the project. In which case, the cost and time estimates would, in theory, equate to historical, objective data rather than a representation of uncertain, subjective estimates made at the project's outset. However, this would not apply for the other respondent-selected contract strategy(s) evaluated for the project.

It should be noted that the decision to introduce Questionnaire 2 had the following effect upon the empirical research:

- It was necessary to retract one of the empirical study's objectives; to ascertain any generalities amongst the industrialists' subjective perceptions about the specific contract strategies and project circumstances presented in Questionnaire 1B.
- Since the prototype model (reported in Chapter 3) was designed to simulate the three specific contract strategies that featured in Questionnaire 1B, it was necessary to extend the model in order to simulate the contract strategies which the respondents of Questionnaire 2 were free to select and evaluate. However, the adjustments to the model were expected to be fairly straightforward because Questionnaire 2 prompts the respondent to define each contract strategy in the same

manner as those featured in Questionnaire 1B.

4.4 Empirical research results

The empirical research results include a brief review of the number and type of empirical research participants. This section also contains summaries of the data collected from the fourteen interviewed industrialists and the six completed questionnaires.

4.4.1 Empirical research participants

Section 4.3.2 reported that seven industrialists were interviewed during a feasibility study. This study took place during March, April and May 1997. The main part of the empirical research was designed and executed once the feasibility study had concluded. Data within the main empirical research were collected up until November 1997.

In the main part of the empirical research seventy five industrialists were asked to participate. Fourteen industrialists contributed to the research (i.e. a response rate of 19%). Each industrialist was assigned a label to maintain their anonymity (see Table 4.3).

Amongst the fourteen participants in the main empirical research were four industrialists who had participated in the feasibility study. They had agreed to be interviewed again, at a later date and to a greater depth. The shaded area of Table 4.3 covers these industrialists.

During the period June to August 1997, fifty industrialists were sent Questionnaire 1B along with a letter enquiring as to whether they would be prepared to discuss the research. From the fifty, only nine industrialists agreed to be interviewed (P2, P3, P4, P5, P8, P9, P10, P11 and P16). From these nine, only two of the industrialists completed Questionnaire 1B (P10 and P16).

During the period August to November 1997, Questionnaire 2 was sent with an accompanying letter to thirty one industrialists which included six of the seven industrialists who had already been interviewed, but had not completed Questionnaire 1B (P2, P3, P4, P5, P8and P9). From the twenty five new industrialists targeted, five agreed to be interviewed (P12, P13, P14, P15 and P17) and three completed Questionnaire 2 (P12, P14 and P15). One of the six previously-interviewed industrialists completed Questionnaire 2 (P4).

Label	Profession	Research Participation
P2	Quantity surveyor/Project manager	Interview
P3	Design consultant/ Project manager	Interview
P4	Quantity surveyor/Project manager	Interview & Questionnaire 2
P5	Quantity surveyor/Project manager	Interview
P8	Design consultant/ Project manager	Interview
P9	Quantity surveyor/Project manager	Interview
P10	Quantity surveyor/Project manager	Interview & Questionnaire 1B
P11	Quantity surveyor/Project manager	Interview
P12	Quantity surveyor/Project manager	Interview & Questionnaire 2
P13	Design consultant/ Project manager	Interview
P14	Design consultant/ Project manager	Interview & Questionnaire 2
P15	Quantity surveyor/Project manager	Interview & Questionnaire 2
P16	Quantity surveyor/Project manager	Interview & Questionnaire 1B
P17	Design consultant/ Project manager	Interview

Table 4.3 The label, profession and participation level of the empirical research industrialists

4.4.2 Interview data

The general design of the interview structure was reported in section 4.3.4. Section 4.3.4 introduced the concept of 'question areas' as, basically, question topics. The following sub-sections deals with each of the eight designed question areas in turn.

An outline of the information and type of questions that the interviewees were presented with in each question area is provided. Then the interviewees' responses to each question area are reported.

The interviewees' responses to each question area have been organised into categorises. In order to categorise the interview data it was necessary to slightly interpret the interviewees' responses. However, the categories have been designed to provide reasonably accurate reflections of each interviewee's expressed perceptions.

The key notes taken for each industrialist interviewed are provided in Appendix B. These notes are paraphrases of the industrialists' comments.

4.4.2.1 Question Area 1

4.4.2.1.1 Description of Question Area 1

Each interview began with a brief introduction to the subject of the research which included a definition of the term 'contract strategy'.

The industrialists were questioned about their usual method of selecting the type of contract strategy to use on a project. The general line of questioning was as follows:

1. Does the industrialist undertake a contract strategy decision process at the beginning of projects?
2. Which criteria do the industrialist aim to satisfy in the decision process?
3. How does the industrialist distinguish between contract strategies in the decision process?

4.4.2.1.2 Responses to Question Area 1

The most notable responses to these questions are summarised as follows:

- All fourteen industrialists had experience with Traditional and Design-Build type contract strategies. All of the industrialists, except P3 and P8, also had experience with Management type contract strategies. None of the industrialists had experienced a contract strategy that did not comprise a standard form of contract, although the majority indicated that normally these standard contract forms were highly amended versions.
- P2, P5, P8, P11, P13 and P17 did not attach a great deal of importance to the contract strategy decisions made at the outset of projects (i.e. those which established the overall organisational and contractual framework). These industrialists perceived that the contract strategy decisions which related to contractual details (e.g. timing of payments, variation clauses) had a more significant impact on a project's price and duration.
- P2, P5 and P11 asserted that there are some projects where they do not undertake an evaluation process because a particular contract strategy is the obvious choice.
- P3, P9 and P15 reported that in some projects the client selects the contract strategy, occasionally overriding an alternative decision recommended by the industrialists.
- P2, P4, P8 and P14 claimed that contract strategy decisions are not expressly made at the outset of some projects, instead they are planned and designed using an incidental arrangement until the contractual details are defined.
- All of the industrialists perceived that different contract strategies had a different impact on the price, duration and quality of projects.

- All of the industrialists reported that a project's contract strategy evaluation process relied upon their experiential knowledge to forecast the likely impacts that different contract strategies would have on the project.
- All of the industrialists were aware of the interrelationship between the price, duration and quality of projects. They all perceived that most clients will either consciously or subconsciously assign different levels of importance to each objective relating to their project's price, duration and quality.
- All fourteen industrialists acknowledged that, for a given project, different contract strategies have different likelihoods of enabling the achievement of the client's prioritised price, time and quality objectives.
- The most commonly cited criteria, with which the industrialists claimed they evaluated the suitability of contract strategies, made reference to the client's price, time and quality objectives, but they also made reference to contract strategies' suitability with respect to a project's circumstances (e.g. the type of client, project size, project type, major project risks, market conditions).
- P9, P11, P12 and P17 asserted that not all factors that influence contract strategy selection relate to cost or time.
- P3, P9, P10 and P15 indicated that the criteria considered in their contract strategy evaluation process were indirect measures of contract strategies' potential impact on a project's price, duration and quality. The industrialist P9 held the view that even quality-related objectives could be considered as a secondary objectives to the clients' price and duration objectives (i.e. the clients' desired quality level is dependent upon the amount of time and money which a client is prepared to expend).

4.4.2.2 Question Area 2

4.4.2.2.1 Description of Question Area 2

The industrialists were asked to give their initial view on the feasibility of undertaking a quantitative evaluation of contract strategies at the outset of projects.

Each of the industrialists' responses can, essentially, be classified into one of the following two categories:

1. a quantitative approach is not feasible because projects present too much uncertainty at their outset and because the perceived differences between contract strategies are subjective.
2. it is possible to quantify, at a project's outset, the impacts that contract strategies are likely to have upon the project's performance.

4.4.2.2.2 Responses to Question Area 2

Table 4.4 shows which category each industrialist's response classifies under.

Industrialist	Category 1 UNFEASIBLE	Category 2 FEASIBLE
P2	x	
P3		x
P4		x
P5	x	
P8	x	
P9		x
P10	x	
P11	x	
P12		x
P13	x	
P14	x	
P15		x
P16	x	
P17	x	

Table 4.4 The industrialists' initial reaction to a quantitative evaluation of contract strategies at the selection stage

The five industrialists who responded positively to this opening question were asked whether they had previously undertaken a quantitative evaluation of contract strategies. The industrialists' answers to this question can be summarised as follows:

- P3 and P4 reported that they had never performed a quantitative evaluation of contract strategies.
- P9, P12 and P15 claimed that, in some projects, the impacts that contract strategies might have on a project's overall price and duration were estimated. However, only P15 had formally reported these estimates at the contract strategy selection stage to aid both the decision and communication with clients.

4.4.2.3 Question Area 3

4.4.2.3.1 Description of Question Area 3

The proposed quantitative approach was described in more detail. The industrialists were informed that the research was investigating whether it was possible to estimate the impacts that contract strategies were likely to have on specific cost and time elements at the outset of a project.

The industrialists were shown a list of the following cost and time elements:

- design cost and duration;
- tender process cost and duration;
- administration costs;
- construction costs and duration;
- contractor's mark-up; and
- project schedule.

A discussion based upon the following two questions ensued:

1. Is it possible to identify and quantify the potential impact that contract strategies could have on these specific cost and time elements at the outset of a project?
2. Is there any value in evaluating alternative contract strategies against the same set of criteria?

4.4.2.3.2 Responses to Question Area 3

The industrialists' responses to this area of questioning can be summarised as follows:

- All fourteen industrialists perceived that different contract strategies could have different impacts on the listed cost and time elements.
- Owing to the high level of uncertainty, all of the industrialists indicated that they could not identify the specific way in which contract strategies could effect each cost and time element at a project's outset. However, P3, P9, P15 and P16 indicated that they could intuitively forecast, in qualitative terms, the relative impacts that different contract strategies could have on the cost and time elements at the outset of projects.
- P9 and P14 expressed a favourable response to the proposal of a methodical evaluation process. They considered that because so many factors need to be considered when evaluating the suitability of a contract strategy there would be value in separating the evaluation process into a series of sub-decisions. In addition, P14 believed that there is a smaller risk of making irrational decisions because the structured process aids the decision-maker to evaluate prospective contract strategies, for each project, in terms of the same key decision criteria.
- Owing to the high level of uncertainty surrounding contract strategy selection at the outset of projects, P2, P5, P8, P11, P13 and P17 claimed that it was more practical to maintain their current approach to contract decisions. The industrialists implied that their current approach was less systematic and more efficient (i.e. focused upon the issues perceived to be the most important). It was also apparent that their current approach relied upon intuitive assumptions which tended to remain implicit.

4.4.2.4 Question Area 4

The industrialists were asked whether they expected particular issues, related to contract strategies, could have any impact on the cost and time elements cited earlier in the interview. The issues concerned fast-track construction, pricing mechanism types, early contractor appointment and the project roles of clients. If the industrialist perceived the issues could have a cost and/or time impact upon a project they were also asked as to whether they perceived it possible to quantify the level of impact at the outset of a project when contract strategy decisions addressing these issues are made.

4.4.2.4.1 Question Area 4i

4.4.2.4.1.1 Description of Question Area 4i

The industrialists were first asked:

Are there some projects where you would expect a contract strategy that enables the design and construction to overlap (i.e. fast-track construction) to reduce the project duration relative to a contract strategy that requires the design and construction to be completed sequentially?

If the industrialist gave an affirmative response to this question the industrialist was then asked:

If, at the outset of a particular project, you perceived a fast-track contract strategy was likely to reduce the project duration relative to a sequential design and construction arrangement, could you give an approximate estimate of the possible time saving?

4.4.2.4.1.2 Responses to Question Area 4i

The industrialists' responses to this area of questioning can be summarised as follows:

- All of the industrialists perceived it possible to identify, at the selection stage of a project, whether time could be saved using fast-track construction.
- P3, P4, P8, P9, P10, P12, P14, P15 and P16 were reasonably confident that, at the contract strategy selection stage of a project, they could give an approximate estimate of the possible time saving.
- P2, P5, P11, P13 and P17 conceded that they could give an approximate estimate of the possible time saving, but stressed that the highly intuitive estimates may lead to ill-founded decisions.

4.4.2.4.2 Question Area 4ii

4.4.2.4.2.1 Description of question Area 4ii

The industrialists were first asked:

Are there some projects where you would expect the contractor's mark-up, including the contractor's profit and the contingency to cover the contractor's risk, to be any different between the two options of paying the contractor on a fixed price basis or paying the contractor on a cost-reimbursable basis?

If the industrialist gave an affirmative response to this question the industrialist was then asked:

If, at the outset of a particular project, you perceived such a difference was probable, could you give an approximate estimate of the possible difference in the contractor's mark-up between these two payment options?

4.4.2.4.2.2 Responses to Question Area 4ii

The industrialists' responses to this area of questioning can be summarised as follows:

- All of the industrialists considered that in most projects the contractor will demand a higher mark-up for a fixed price type pricing mechanism than for a cost reimbursable type.
- All of the industrialists indicated that they could estimate the contractor's mark-up. In many cases, the industrialists suggested that their ability to make this estimate was dependent upon the information available at the time of the estimates. The type of information that they referred to included details of the contract strategy (i.e. its risk allocation), general project details and details of the particular contractor organisation that is awarded the contract.

4.4.2.4.3 Question Area 4iii

4.4.2.4.3.1 Description of Question Area 4iii

The industrialists were first asked:

Are there some projects where you would expect a contract strategy that enables a contractor to contribute to the design and planning stages of the project, to lead to any cost and time savings relative to a contract strategy that does not accommodate early involvement of a contractor?

If the industrialist gave an affirmative response to this question the industrialist was then asked:

If, at the outset of a particular project, you perceived the early involvement of a contractor was likely to lead to cost and time savings, could you give an approximate estimate of these possible savings?

4.4.2.4.3.2 Responses to Question Area 4iii

The industrialists' responses to this area of questioning can be summarised as follows:

- P4, P9, P10, P13, P14, P15 and P16 perceived that in some projects the contractor's involvement at the design and planning stages can result in cost and time savings. Each of these industrialists claimed that they would be prepared to speculate, at the outset of a project, as to whether advantages could be gained from early contractor involvement. However, only P14 and P16 showed an inclination to quantify their subjective assumptions.
- P2, P3, P11 and P17 perceived that in some projects the contractor's involvement at the design and planning stages can result in cost and time savings. However, owing to the uncertainty at a project's outset, they asserted that the impact of early contractor involvement could not be identified and quantified until a later project stage.
- P5, P8 and P12 considered that a contractor's involvement at the design and planning stages of a project did not lead to any cost and time savings.

4.4.2.4.4 Question Area 4iv

4.4.2.4.4.1 Description of Question Area 4iv

The industrialists were first asked:

Are there some projects where you would expect the project price and duration to be any different between the two options of the client taking an active role during the project and the client having a very limited involvement once the main contract was awarded?

If the industrialist gave an affirmative response to this question the industrialist was shown the list of cost and time elements and asked:

If, at the outset of a particular project, you perceived such a difference was probable, could you:

1. identify which cost and time elements were likely to be affected by each of these two types of client involvement; and
2. give an approximate estimate of these identified cost and time elements incorporating the probable impact of the type of client involvement?

4.4.2.4.4.2 Responses to Question Area 4iv

The industrialists' responses to this area of questioning can be summarised as follows:

- Many of the industrialists considered that the type of client and the type of client involvement in a project can influence a project's cost and time performance. However, all of the industrialists, except P10 and P14, perceived that the high level of uncertainty at the selection stage made it impossible to make subjective evaluations about the level of impact that different types of client and of client involvement may have on the cost and time elements.
- P10 and P14 held a similar view to the other industrialists except they claimed in some circumstances it is possible at the selection stage, to identify whether avoidable costs and delays will be incurred as a result of the client's active involvement in the project. Furthermore, in such a case, P10 and P14 claimed that they could give a highly intuitive estimate of the cost and time elements incorporating this subjective judgement.

4.4.2.5 Question Area 5

4.4.2.5.1 Description of Question Area 5

The industrialists were given a brief explanation about uncertainty and how it can be accounted for in quantitative estimates using triangular probability distributions.

The industrialists were then asked whether the application of these probability techniques alleviated any of their reservations about:

1. making subjective assumptions about contract strategies' likely impacts upon a project's cost and time elements at the selection stage; and
2. translating these subjective assumptions into quantitative estimates.

4.4.2.5.2 Responses to Question Area 5

The industrialists' responses to this area of questioning can be summarised as follows:

- P2, P4, P8, P10, P12, P16 and P17 supported the use of probability distributions in so far as they perceived it more pertinent to estimate a range of values rather than a single value for each cost and time element because of the high level of uncertainty at the outset of projects. However, only P4, P10 and P16 considered that they may be able to incorporate their subjective assumptions about contract strategies into probability distribution estimates for each cost and time element.
- P3, P5, P8, P9, P11, P13, P14 and P15 did not make any noteworthy comments about the applicability of probability distribution estimates. Nevertheless, P3, P9, P14 and P15 acknowledged that the quantitative approach could be feasible.

- P2, P11, P13 and P17 maintained that the quantitative approach was unfeasible owing to the considerable uncertainty at the outset of projects and the uncertainty in their subjective assumptions about contract strategies.

4.4.2.6 Question Area 6

4.4.2.6.1 Description of Question Area 6

The industrialists were asked whether they would be prepared to complete a questionnaire in order to perform an example application of the quantitative approach. Owing to the protracted period during which the questionnaires were developed, some of the industrialists were asked to complete Questionnaire 1B while other industrialists were asked to complete Questionnaire 2.

4.4.2.6.2 Responses to Question Area 6

Table 4.5 summarises:

1. which industrialists' expressed a willingness to complete a questionnaire;
2. which type of questionnaire each industrialist agreed to complete;
3. under which circumstances the industrialists preferred to complete a questionnaire; and
4. which industrialists completed a questionnaire.

The industrialists' questionnaire responses are reported in Section 4.4.3 At this stage, the interview sometimes changed according to whether the industrialist had agreed to complete a questionnaire. Nonetheless, all of the industrialists' interviews included Question Areas 7 and 8.

Industrialist (Questionnaire Type)	Industrialists' Reactions to Question Area 6
P2 (Questionnaire 1B) P3 (Questionnaire 1B) P5 (Questionnaire 2) P8 (Questionnaire 2) P9 (Questionnaire 2)	These industrialists agreed to complete a questionnaire in their own time after the interview, but did not complete the questionnaire.
P4 (Questionnaire 2) P16 (Questionnaire 1B)	These industrialists agreed to complete a questionnaire in their own time after the interview and did complete the questionnaire. The industrialists reasons for their estimates were collected during interviews conducted at a later date.
P10 (Questionnaire 1B) P12 (Questionnaire 2) P14 (Questionnaire 2) P15 (Questionnaire 2)	These industrialists completed the questionnaire during the interview.
P11 P13 P17	These industrialists did not wish to complete a questionnaire.

Table 4.5 Summary of the industrialists' reactions once asked whether they would be prepared to complete a questionnaire

4.4.2.7 Question Area 7

4.4.2.7.1 Description of Question Area 7

The industrialists were introduced to the prototype model described in Chapter 3. The prototype model was described as providing a framework to input probability distribution estimates of a project's cost and time elements for each contract strategy under evaluation (i.e. it is intended that any subjective assumptions about a contract strategy's probable impact on these cost and time elements are incorporated into the estimates). The model description made reference to Monte Carlo simulation. Subsequently, the industrialists were presented with example model output for two different contract strategies (Figure 4.4).

The industrialists were then questioned about:

1. whether the type of data, displayed in the example results, could be of assistance to contract strategy selection;
2. the practicality the model.

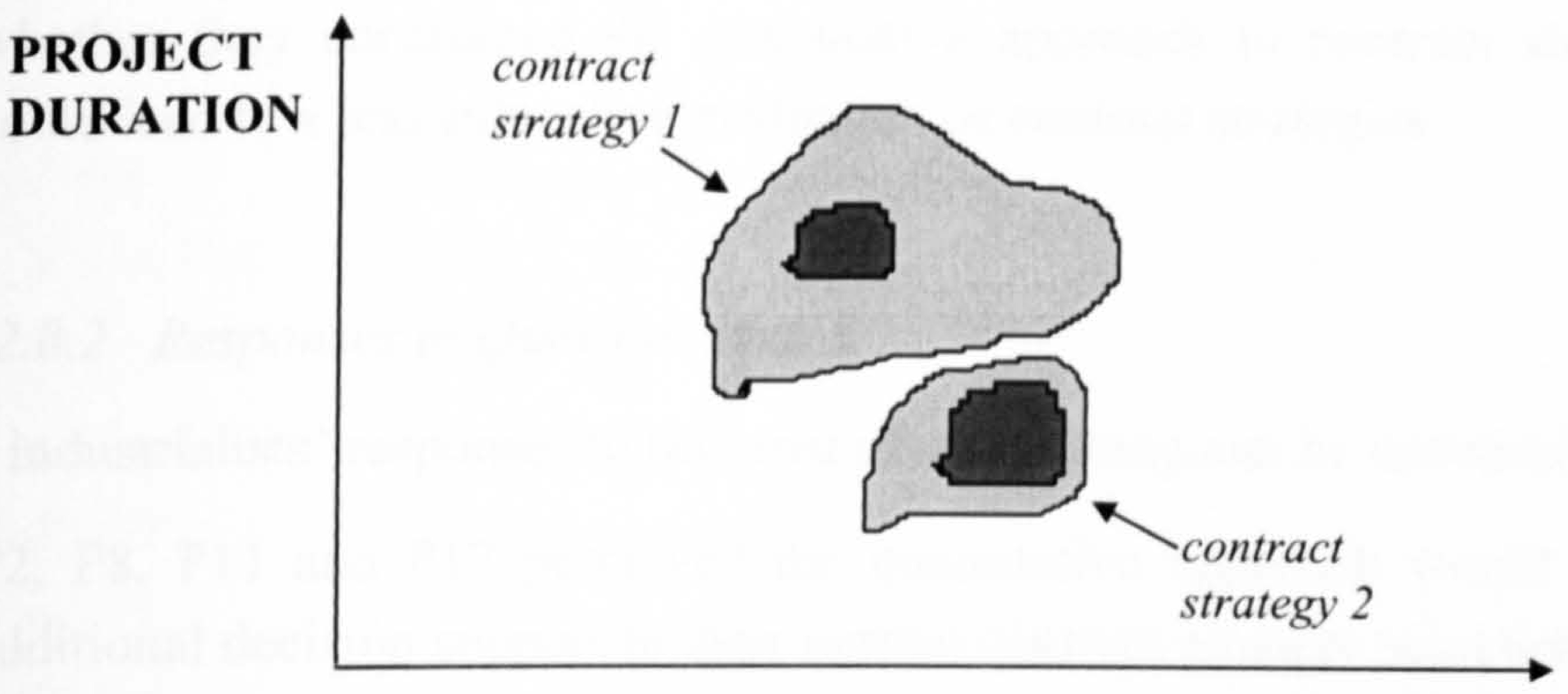


Figure 4.4 The example set of results shown to industrialists during the interview

4.4.2.7.2 Responses to Question Area 7

The industrialists' responses to this area of questioning can be summarised as follows:

- All of the industrialists except P11, P13 and P17 indicated that the results provided a useful overview of the likely differences between contract strategies.
- P8, P10, P14, P15 and P16 appreciated the quantitative nature of the results since they recognised that it was possible to measure the differences between contract strategies in quantitative terms and also measure whether contract strategies were likely to enable the achievement of project price and duration targets.
- P5, P8, P10, P12, P14 and P16 perceived the results provided a useful means of reporting their evaluation of contract strategies, particularly to clients at the selection stage of projects.
- P4, P5, P8, P11, P12 and P13 claimed the model and its required evaluation process was impractical because of the time and money constraints at the beginning of projects when the contract strategy is selected.
- P5, P8, P11, P13, P14, P16 and P17 expressed concerns about the value of the model based upon the observation that the results would simply reflect, and even magnify, the high level of uncertainty and subjectivity that a model-user inputs into the model.

4.4.2.8 Question Area 8

4.4.2.8.1 Description of Question Area 8

At this final stage of the interview the industrialists were questioned about:

1. whether they would prefer to perform a less subjective evaluation of contract strategies; and

2. whether they considered the quantitative approach to contract strategy evaluation could lead to a less subjective evaluation of contract strategies.

4.4.2.8.2 Responses to Question Area 8

The industrialists' responses to this area of questioning can be summarised as follows:

- P2, P8, P11 and P17 perceived the quantitative approach would not provide any additional decision support to their normal contract strategy selection process.
- P2, P10, P11, P12 and P17 commented that the high level of uncertainty which projects present at the contract strategy selection stage was compounded by the fact that every project is individual. These industrialists considered that attempting to acquire a more scientific understanding of the impacts that contract strategies have had on completed projects is unlikely to be of assistance on future projects because the decision will always have to rely upon subjective judgement.
- P2, P5, P8, P11, P13 and P17 claimed that the quantitative approach to contract strategy evaluation focused too heavily upon the decision which is made at the beginning of projects. These industrialists expressed the view that the important decisions relating to contractual arrangements were not necessarily made at the beginning of projects. Therefore they insisted that contract strategy evaluation at the beginning of projects did not warrant the level of effort that the quantitative approach demands.
- P3, P4, P9, P10, P14, P15 and P16 considered that that there is a need to understand more about the cost and time impacts that contract strategies have had on completed projects because this may lead to less subjective evaluations of contract strategies.
- P3 and P14 commented that the quantitative approach to contract strategy evaluation may help to understand more about the cost and time impacts that contract strategies have had on completed projects.
- P4, P9 and P14 indicated that the breakdown of the evaluation process into a series of decisions resulted in a more manageable and deservedly more rigorous evaluation of contract strategies.
- P14 perceived that quantification of subjective assumptions about contract strategies demanded more consideration and justification than making the initial subjective assumption. Consequently, he said that the quantification process provided a useful safeguard against irrational decisions being made instinctively.
- P3, P4, P14 and P16 also highlighted that many of the important decisions are not necessarily made at the beginning of projects, but remarked that they would prefer to make these decisions at the beginning of projects because this would lead to better-managed projects.

4.4.3 The questionnaire data

Six of the fourteen industrialists who were interviewed completed questionnaires (P4, P10, P12, P14, P15 and P16). Two of these industrialists (P10 and P16) completed Questionnaire 1B while the other four completed Questionnaire 2.

The questionnaire responses include quantitative estimates of cost and time that reflect the impact of contract strategies upon specific projects. The responses also include the industrialists' justifications for their estimates. The quantitative estimates were processed using the prototype model reported in Chapter 3 to calculate a distribution of project price and duration for each contract strategy evaluated. The following sections present the calculated distributions together with the estimates and reasons for all six completed questionnaires. However, it was decided to focus upon the responses gained from three questionnaire respondents while the other three are summarised briefly.

4.4.3.1 Data gained from Questionnaire 1B

Section 4.3.3 described Questionnaire 1B in detail and a copy of Questionnaire 1B is provided in Appendix A. It presents the respondent with a hypothetical project and three contract strategy alternatives. The respondent is requested to reflect the expected impact of each contract strategy upon the project in estimates of the project's constituent cost and time elements.

The project is described as a seven-storey concrete-framed office block that is to provide a gross floor area of $10{,}000m^2$. Some preliminary design of the building has been performed (details are provided in the questionnaire - see Appendix A). The brown-field site is located on the outskirts of a city centre where traffic congestion is not uncommon. The overall project cost and duration are roughly estimated at £8 million and 21 months.

The client is an insurance company that wishes to occupy the building once complete. The company has had very little construction experience and has no in-house resources to assist in administering the project.

Table 4.6 outlines details of the contract strategies presented in Questionnaire 1B.

Although P10 and P16 were presented with the same contract strategy decision problem, it was not considered valid to compare the two industrialists' questionnaire responses because the decision problem is open to considerable interpretation. This is particularly evident by the fact that there was a maximum difference of £5million between the project price results calculated from the two industrialists' estimates (see Figures 4.6 and 4.8)

Contract Strategy 1: CS 1	
Organisational structure	Traditional
Tender process	Full bill of quantities used to negotiate a Guaranteed Maximum Price (GMP)
Pricing mechanism	GMP (if construction price is less than the GMP then the savings are shared equally between the client and contractor, but the contractor is solely responsible for all costs over the GMP)
Contract Strategy 2: CS 2	
Organisational structure	Design-Build
Tender process	Competitive single-stage on the basis of fixed price
Pricing mechanism	Fixed price
Contract Strategy 3: CS 3	
Organisational structure	Management Contract
Tender process (management contractor)	Pre-qualification followed by negotiation of fees
Tender process (each works contractor)	Competitive single-stage
Pricing mechanism (management contractor)	Pre-construction lump sum fee and fee (for during-construction services) is a fixed percentage of the construction cost plus any savings or overruns relative to a negotiated target cost are shared equally between client and management contractor
Pricing mechanism (works contractors)	cost plus percentage fee

Table 4.6 The contract strategies presented in Questionnaire 1B

4.4.3.1.1 Questionnaire responses from industrialist P10

The following sub-sections describe the questionnaire responses from P10 in detail. A copy of the questionnaire completed by P10 is provided in Appendix C.

4.4.3.1.1.1 The estimates provided by P10

Figure 4.5 shows the estimates provided by P10.

It is important to note that the industrialist P10 estimated a minimum, most likely and maximum Guaranteed Maximum Price for two variations of the Traditional contract strategy. The first set of Guaranteed Maximum Price values were based upon the assumption that the construction contractor's accounts would be accessible to the client (i.e. open book accounting). The second set of Guaranteed Maximum Price values were based upon the assumption that the construction contractor's accounts would not be accessible to the client (i.e. closed book accounting). The industrialist's estimates of the cost and time elements that precede the tender bid parameters estimates do not differentiate between these variations of the Traditional contract strategy. However, where the tender bid parameter estimates and processed results are presented, the Traditional contract strategy is referred to as CONTRACT STRATEGY 1A (OPEN) and CONTRACT STRATEGY 1B (CLOSED).

4.4.3.1.1.2 The reasoning behind the estimates provided by P10

- ***The range of each element's estimate.*** P10 focused upon the most likely value estimated for each cost and time element and did not evaluate the uncertainty related to each element. It was apparent that the minimum and maximum values estimated by P10 were simply intended to cover the same range as the estimates presented in the questionnaire for CS 1.
- ***Design cost.*** P10 claimed that the design would cost the least if CS 2 was used because CS 2 produces an efficient design. P10 considered that the design would cost the most if CS 3 was used because under this arrangement there is a tendency for the parties involved to be unsure as to their precise roles and thus additional costs would be incurred.
- ***Design duration.*** P10 perceived that the design duration would be the same under CS 1 and CS 2, but slightly longer under CS 3. This is because P10 claimed that the longer design duration estimated for CS 3 was intended to reflect the need for more co-ordination because more parties would be involved at the design stage if CS 3 was used.
- ***Tender process cost and duration.*** P10 considered that the competitive tender process used by CS 2 would take the same period of time, but cost the client slightly less than the negotiated tender process used in CS 1. P10 claimed that the direct costs which the client incurs are generally expected to be higher for a negotiated tender process than a competitive process. P10 estimated a higher cost and longer duration for the tender process used in CS 3 compared to those estimated for the other two contract strategies. P10 explained that the estimates for CS 3 reflected the series of tendering demanded by the nature of CS 3.
- ***Transaction costs.*** P10 estimated the same transaction costs for all three contract strategies and this estimate was the same as that presented in the questionnaire for CS 1. The industrialist indicated that he was unsure as to what to include in this cost element.

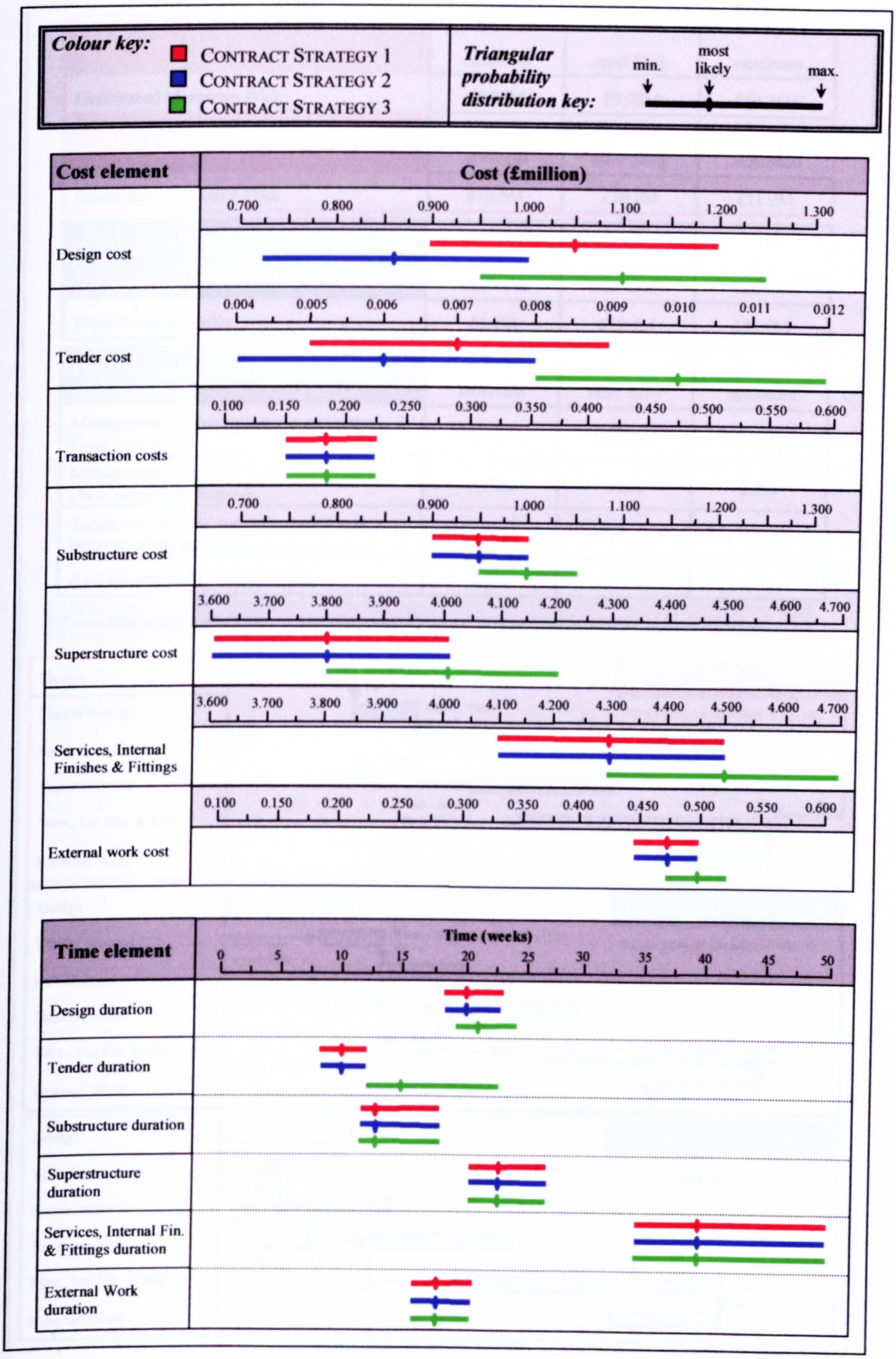


Figure 4.5 Questionnaire estimates provided by industrialist P10 *(continued overleaf)*

CONTRACT STRATEGY 1A (OPEN) most likely total construction cost* = £9.525M	minimum	most likely	maximum
Guaranteed Maximum Price	£9.25M	£9.75M	£10.25M

CONTRACT STRATEGY 1B (CLOSED) most likely total construction cost* = £9.525M	minimum	most likely	maximum
Guaranteed Maximum Price	£10.0M	£10.5M	£11.0M

CONTRACT STRATEGY 2 most likely total design and construction cost* = £10.4M	minimum	most likely	maximum
Fixed lump sum price	£9.8M	£10.4M	£11.0M

CONTRACT STRATEGY 3 most likely total construction cost* = £10.0M	minimum	most likely	maximum
Management contractor's pre-construction lump sum fee	£0.020M	£0.025M	£0.035M
Management contractor's fee (% of construction costs)	1.75%	2.0%	2.5%
Target construction cost value negotiated between client and management contractor	£9.75M	£10.25M	£10.75M
Average works contractors' % fee	2.0%	2.5%	3.0%

*** most likely total cost calculated approximately as the summation of the appropriate element's most likely cost values**

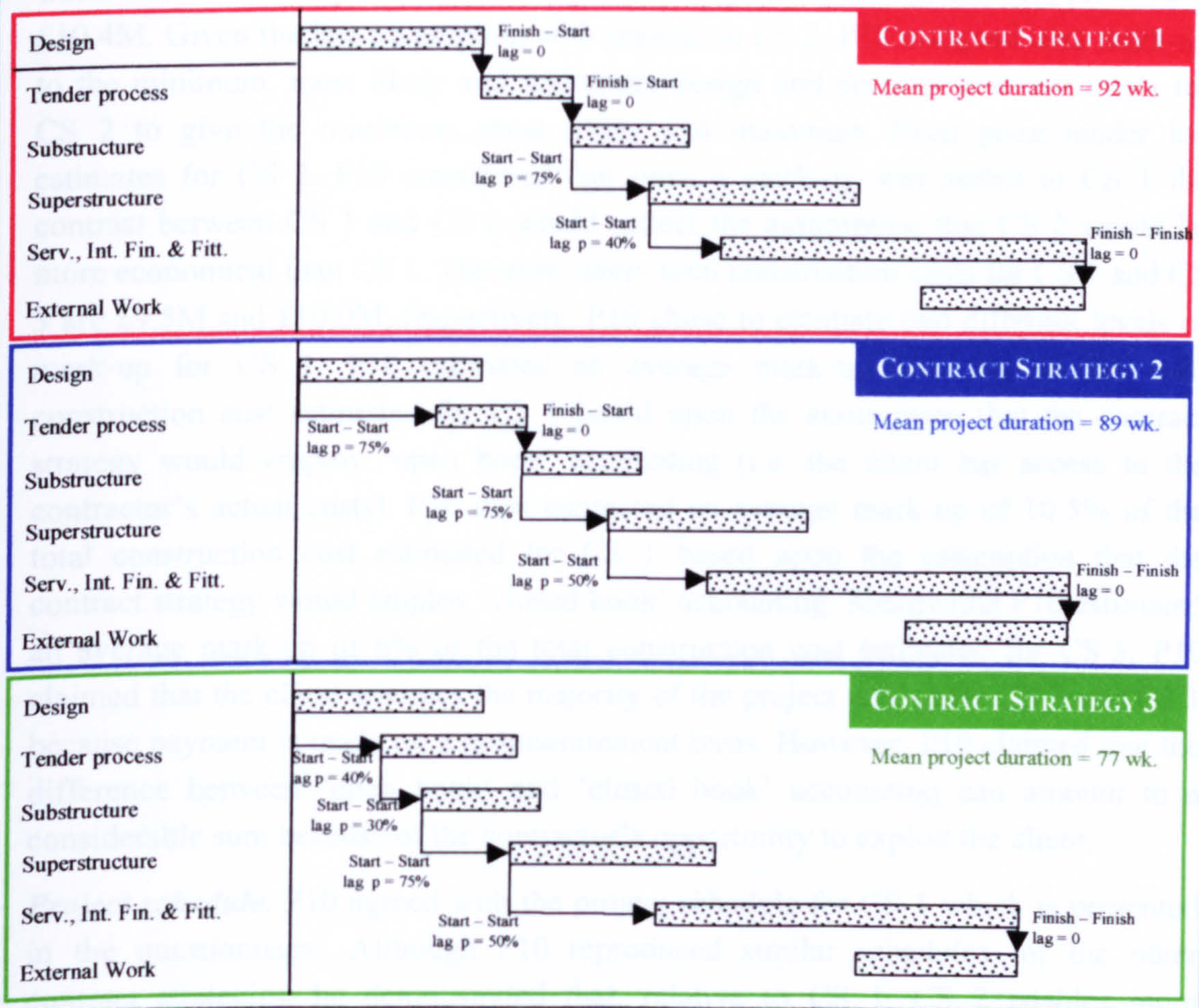


Figure 4.5*(continued)* Questionnaire estimates provided by industrialist P10

- ***The cost and duration of all the construction components (i.e. substructure superstructure, services, internal finishes, fittings and external work).*** For each construction component, P10 estimated the same duration for all three contract strategies (and each component's duration estimate was the same as that provided in the questionnaire). P10 explained that it was difficult to relate to the particular circumstances of the hypothetical project and thus it was difficult to speculate about the contract strategies' potential impact on the project. P10 made reference to this issue again when asked to reason why the same cost values had been estimated for CS 1 and CS 2. However, following the summation of the construction cost totals P10 claimed that the construction cost total for CS 2 ought to be less than that of CS 1, not the same. He attributed this assumption to his experience and indicated that the contractor, under CS 2, had more incentive to minimise costs. However, P10 chose not to refine the construction cost estimates. Instead he reflected this late assumption in the fixed price tender bids for CS 2 (see Figure 4.5). When P10 was asked to explain why he had estimated higher costs for the construction components under CS 3 than those for CS 1 and CS 2 he claimed that the additional cost was intended to reflect the fact each construction component would be undertaken by different contractors. He perceived this would inevitably increase costs.

- ***Contractor's mark-up.*** The most likely total design and construction cost for CS 2 is £10.4M. Given the late assumption with regards to CS 2, P10 assigned zero mark-up to the minimum, most likely and maximum design and construction cost totals for CS 2 to give the minimum, most likely and maximum fixed price tender bid estimates for CS 2. P10 considered that once a mark-up was added to CS 1 the contrast between CS 1 and CS 2 would reflect the assumption that CS 2 would be more economical than CS 1. The most likely total construction costs for CS 1 and CS 3 are £9.5M.and £10.0M, respectively. P10 chose to estimate two different levels of mark-up for CS 1. P10 estimated an average mark-up of 7.9% of the total construction cost estimated for CS 1 based upon the assumption that the contract strategy would employ 'open book' accounting (i.e. the client has access to the contractor's actual costs). P10 then estimated an average mark-up of 10.5% of the total construction cost estimated for CS 1 based upon the assumption that the contract strategy would employ 'closed book' accounting. Meanwhile P10 estimated an average mark-up of 6% of the total construction cost estimated for CS 3. P10 claimed that the client assumes the majority of the project risk under CS 3 and CS 1 because payment is made on a re-measurement basis. However, P10 claimed that the difference between 'open book' and 'closed book' accounting can amount to a considerable sum because of the contractor's opportunity to exploit the client.

- ***Project schedule.*** P10 agreed with the project schedule for CS 1 which is presented in the questionnaire. Although P10 reproduced similar schedules for the other contract strategies, he demonstrated that, relative to CS 1, CS 2 enables more activities to overlap while CS 3 enables even more activities to overlap. P10 explained that the estimated schedules realistically show that the project would be completed within the shortest period under CS 3 and within the longest period under CS 1.

4.4.3.1.1.3 The reaction of P10 to the results

Figure 4.6 shows the results calculated from the estimates provided by P10. The results for each evaluated contract strategy are presented as a contour plot.

P10 agreed with the general ordering of the contract strategies' contour plots. For example, he agreed that the project price results of CS 2 ought to cover a lower part of the price scale than those of CS 1 and also agreed that the project price results of CS 1 ought to cover a lower part of the price scale than those of CS 3. He expressed a similar response about the project duration results.

However, P10 indicated some concern about the reliability of the specific price and duration values calculated for each contract strategy. He stated that the way in which the results were presented (Figure 4.6) could be misleading. He claimed that the results may be interpreted without appreciating the fact that the results derived from approximate and highly speculative estimates.

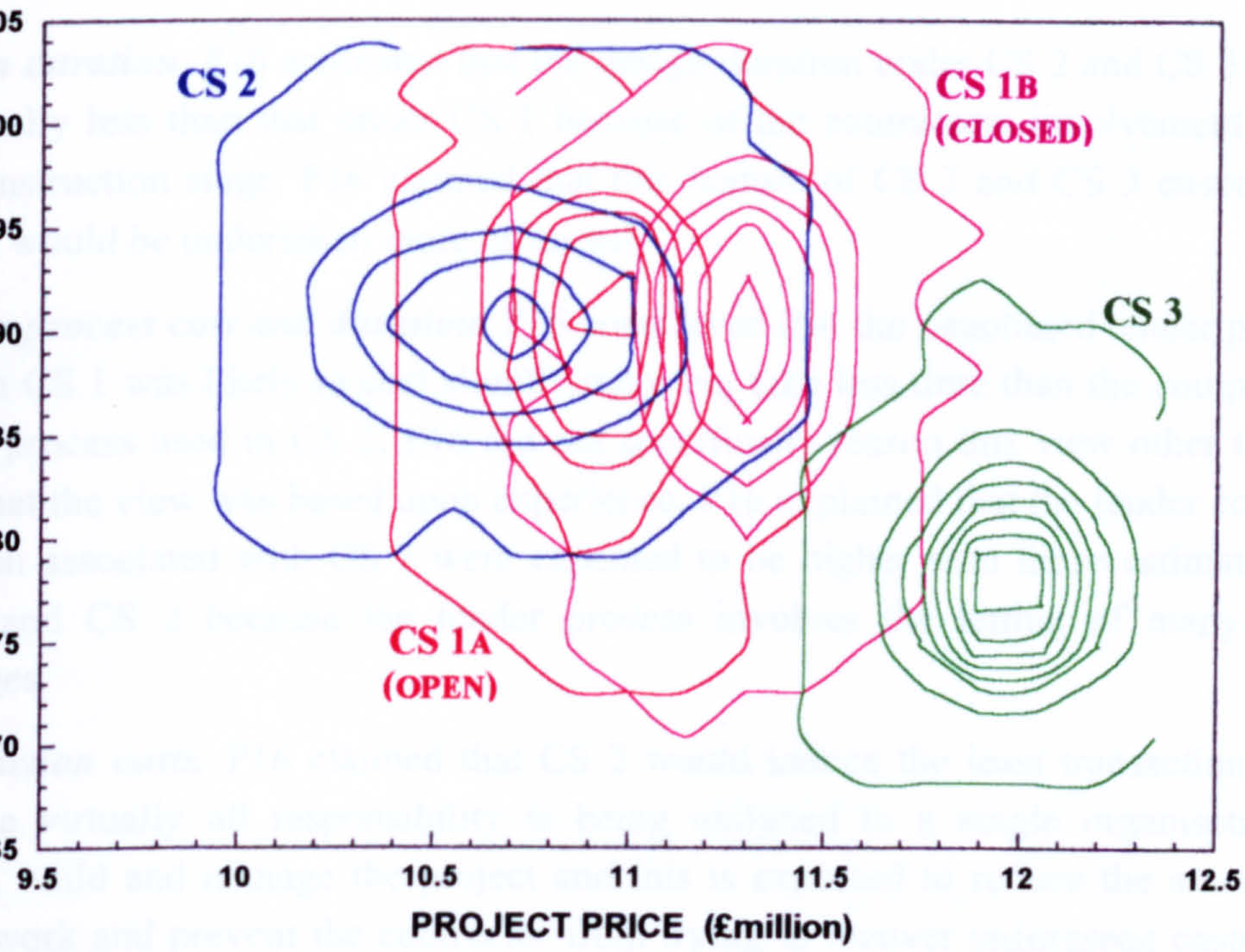


Figure 4.6 Results calculated from the estimates provided by P10

4.4.3.1.2 Questionnaire responses from industrialist P16

The following sub-sections describe the questionnaire responses from P16 in detail. A copy of the questionnaire completed by P16 is provided in Appendix C.

4.4.3.1.2.1 The estimates provided by P16

Figure 4.7 shows the estimates provided by P16.

4.4.3.1.2.2 The reasoning behind the estimates provided by P16

- ***The range of each element's estimate.*** P16 stated that the probability distribution of values estimated for the cost and time elements were intended to reflect the potential level of risk related to the elements which could occur. P16 did not clarify which specific risks were related to the cost and time elements.
- ***Design cost.*** P16 perceived that the design would cost the least under CS 2. P16 said that relative to CS 1 and CS 3, the amount of work involved in the design, particularly during the detailed design stage, would be reduced if the designer is also the builder. P16 also claimed that design consultants appointed by a contractor have a tendency to receive a smaller fee than if they were appointed by the client. P16 estimated that the design would cost slightly more for CS 3 than for CS 1 because letting the construction in packages under CS 3 generates additional costs.
- ***Design duration.*** P16 estimated that the design duration under CS 2 and CS 3 would be equally less than that under CS 1 because of the contractors involvement at the pre-construction stage. P16 claimed that this feature of CS 2 and CS 3 ensured the design would be undertaken more efficiently.
- ***Tender process cost and duration.*** P16 considered that the negotiated tender process used in CS 1 was likely to cost slightly more but take less time than the competitive tender process used in CS 2. P16 did not specifically reason this view other than to state that the view was based upon experience. P16 explained that the tender cost and duration associated with CS 3 were expected to be higher than those estimated for CS 1 and CS 2 because the tender process involves the letting of many work packages.
- ***Transaction costs.*** P16 claimed that CS 2 would induce the least transaction costs because virtually all responsibility is being assigned to a single organisation to design, build and manage the project and this is expected to reduce the amount of paper work and prevent the contractor from trying to recover unforeseen costs. P16 considered that the client was likely to incur the highest transaction costs under CS 3 because this contract strategy presents the client with a greater risk of cost uncertainty. Therefore P16 claimed that the client will need to employ considerable cost monitoring resources if CS 3 was used.

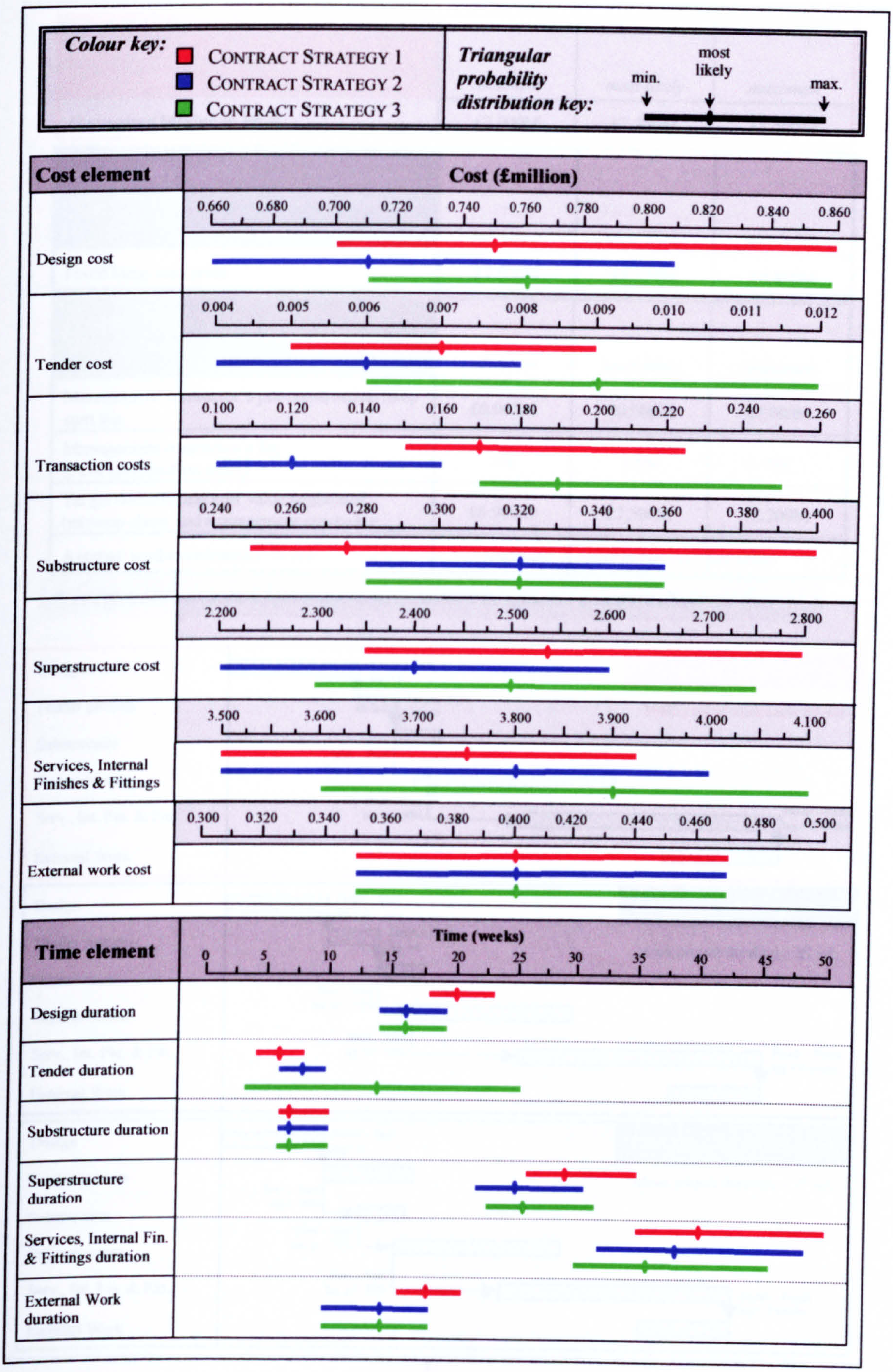


Figure 4.7 Questionnaire estimates provided by industrialist P16 *(continued overleaf)*

Contract Strategy 1 most likely total construction cost* = £7.01M	*minimum*	*most likely*	*maximum*
Guaranteed Maximum Price	£7.000M	£7.250M	£8.500M

Contract Strategy 2 most likely total design and construction cost* = £7.75M	*minimum*	*most likely*	*maximum*
Fixed lump sum price	£7.500M	£8.150M	£8.850M

Contract Strategy 3 most likely total construction cost* = £7.12M	*minimum*	*most likely*	*Maximum*
Management contractor's pre-construction lump sum fee	£0.040M	£0.060M	£0.080M
Management contractor's fee (% of construction costs)	3%	3.5%	5%
Target construction cost value negotiated between client and management contractor	£6.900M	£7.500M	£8.200M
Average works contractors' % fee	*(included in construction cost estimates)*		

*** most likely total cost calculated approximately as the summation of the appropriate element's most likely cost values**

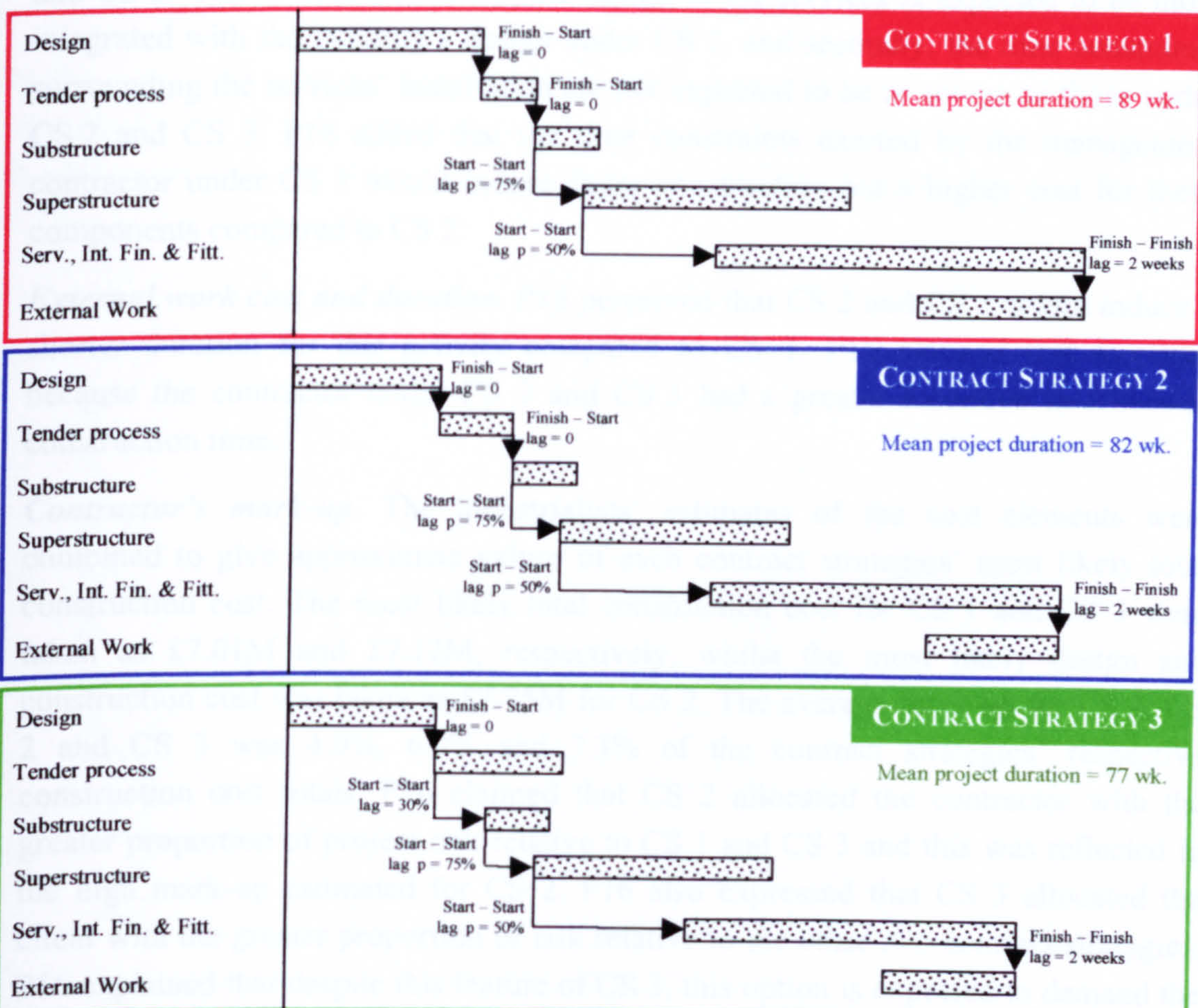


Figure 4.7 *(continued)* Questionnaire estimates provided by industrialist P16

- ***Substructure costs and duration.*** P16 expected that the substructure would be completed within the same period of time regardless of which of the three contract strategies was used. P16 also expected the substructure to cost the same if either CS 2 or CS 3 were used, but cost slightly more if CS 1 was used. P16 claimed that the early involvement of the contractor under CS 2 and CS 3 was likely to lead to some buildability cost savings relative to CS 1. P16 also made reference to the likelihood that the early involvement of the contractor will ensure construction plant and materials will be available when required.

- ***Superstructure costs and duration.*** P16 estimated that the superstructure cost and duration would be highest under CS 1. P16 again made reference to cost and time savings ensuing from the contractor's involvement during the design stage under CS 2 and CS 3. P16 perceived that these buildability savings would be greater under CS 2 than CS 3 because under CS 2 the contractor has a greater incentive to produce a cost effective design and work at a higher productivity rate.

- ***Services, internal finishes and fittings cost and duration.*** P16 estimated that these construction components would cost the least under CS 1. P16 claimed that the building's services were likely to incur fewer problems under CS 1 than under CS 2 and CS 3. This is because, firstly, the design of the services is expected to be more integrated with the building's design under CS 1, and secondly, the time constraints surrounding the services' installation are not expected to be as severe as those under CS 2 and CS 3. P16 added that the time constraints exerted by the management contractor under CS 3 would induce faster construction but a higher cost for these components compared to CS 2.

- ***External work cost and duration.*** P16 perceived that CS 2 and CS 3 would induce a shorter duration for this activity compared to CS 1. P16 claimed that this was because the contractor under CS 2 and CS 3 had a greater incentive to minimise construction time.

- ***Contractor's mark-up.*** The industrialists' estimates of the cost elements were combined to give approximate values of each contract strategies' most likely total construction cost. The most likely total construction cost for CS 1 and CS 3 were taken as £7.01M and £7.12M, respectively, whilst the most likely design and construction cost was taken as £7.75M for CS 2. The average mark-up for CS 1, CS 2 and CS 3 was 4.0%, 6.0% and 7.3% of the contract strategies' respective construction cost totals. P16 claimed that CS 2 allocated the contractor with the greater proportion of project risk relative to CS 1 and CS 3 and this was reflected in the high mark-up estimated for CS 2. P16 also expressed that CS 3 allocated the client with the greater proportion of risk relative to the other two contract strategies. P16 explained that despite this feature of CS 3, this option is expected to demand the highest mark-up.

- ***Project schedule.*** P16 virtually replicated the project schedule provided in the questionnaires (which was estimated for CS 1) for all three contract strategies. The project schedule estimated for each contract strategy accounted for each contract strategy's different time estimates, but this was the only aspect used to distinguish between their impact on the project schedule. The estimated project schedules indicated that P16 perceived that the project was likely to be completed within a similar period if CS 2 or CS 3 was used, but the project duration would be longer if CS 1 was used. Another significant aspect of the schedule estimates was that P16 considered that under all three contract strategies the design would be complete before construction commenced.

4.4.3.1.2.3 The reaction of P16 to the results

Figure 4.8 shows the results calculated from the estimates provided by P16. The results for each evaluated contract strategy are presented as a contour plot.

P16 stated that he did not expect the mean price value for CS 2 to be slightly higher than that of CS 1. P16 expressed that this presumption was based upon experience. He indicated that he expected a Design-Build type arrangement, for this type of project, to induce the lowest project price relative to the other two contract strategy options.

He did not wish to review or revise his original estimates. With the exception of the price results for CS 2, P16 considered the results provided an adequate representation of his perception about the differences between the three contract strategies.

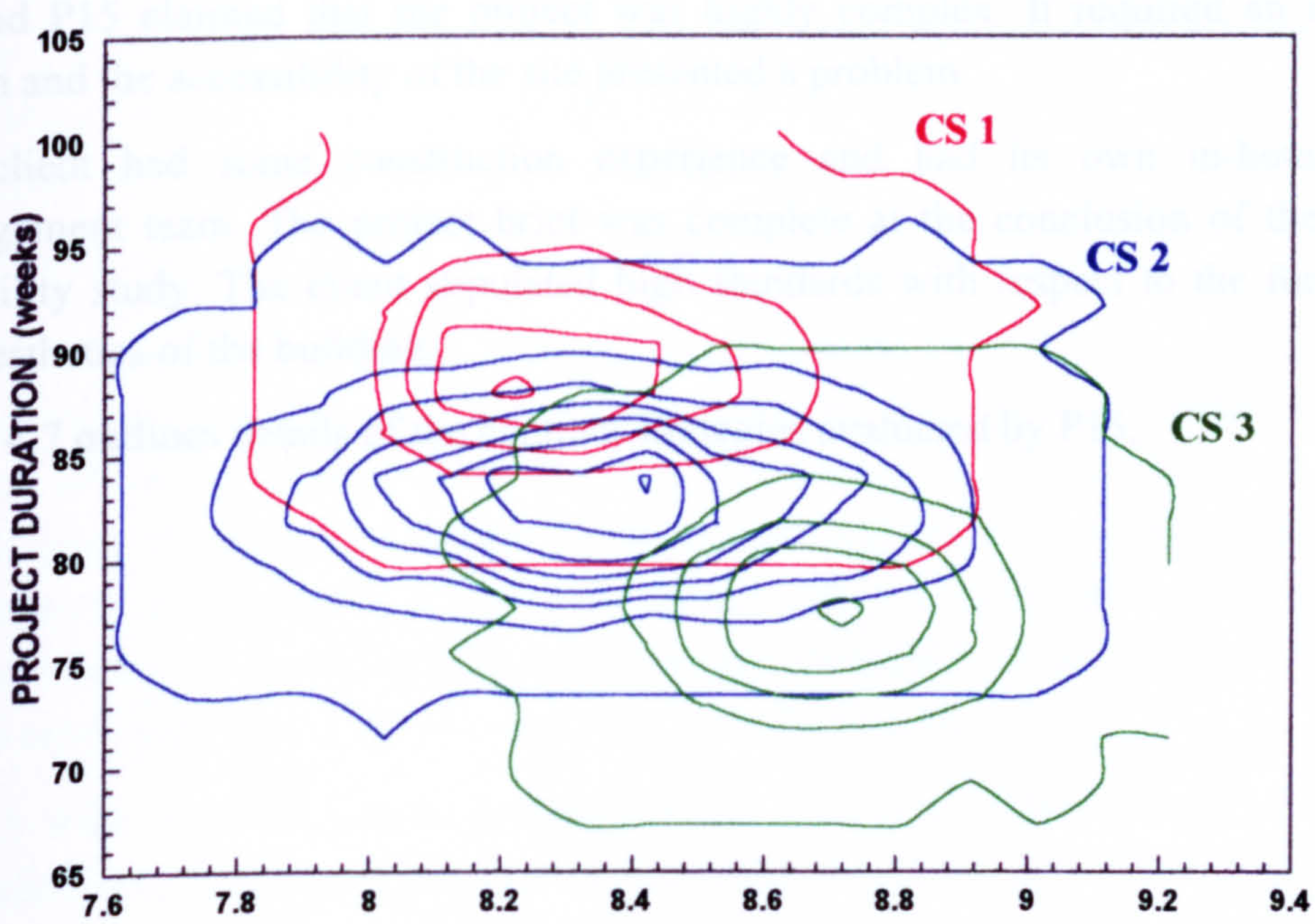


Figure 4.8 Results calculated from the estimates provided by P16

4.4.3.2 Data gained from Questionnaire 2

Section 4.3.4 described Questionnaire 2 and a copy of Questionnaire 2 is provided in Appendix A. Questionnaire 2 requests the respondent to evaluate any contract strategies for a project that the respondent had been involved in. Therefore, in addition to the industrialists' estimates and their justifications, the responses to Questionnaire 2 includes details of the project and contract strategies which the respondent chose to consider (in contrast to Questionnaire 1B that provided these details).

The data gained from the four industrialists who completed Questionnaire 2 (P4, P12, P14 and P15) are reported in the subsequent sub-sections.

The questionnaire responses provided by one of the four industrialists (P15) who completed Questionnaire 2 are reported in detail. Meanwhile the other three industrialists' questionnaire responses are summarised.

4.4.3.2.1 Questionnaire responses from industrialist P15

The following sub-sections describe the questionnaire responses from P15 in detail. A copy of the questionnaire completed by P15 is provided in Appendix C.

4.4.3.2.1.1 Description of the decision problem considered by P15

The project was described as a learning resource centre (i.e. a library building). The building was built on a brown-field site located in a city centre. The project was a one-off and P15 claimed that the project was highly complex. It required an innovative design and the accessibility of the site presented a problem.

The client had some construction experience and had its own in-house project management team. The project brief was complete at the conclusion of the project's feasibility study. The client stipulated high standards with respect to the functionality and aesthetics of the building.

Table 4.7 outlines details of the contract strategies evaluated by P15.

Contract Strategy 1: CS 1	
Organisational structure	Traditional
Tender process	Competitive single stage based on full bill of quantities
Pricing mechanism	Lump sum

Contract Strategy 2: CS 2	
Organisational structure	Management Contract
Tender process (management contractor)	Competitive on the basis of management fees
Tender process (each works contractor)	Competitive on the basis of a specification and drawings
Pricing mechanism (management contractor)	Fixed percentage of the construction price
Pricing mechanism (works contractors)	Lump sum or cost plus fixed fee

Table 4.7 The contract strategies chosen and evaluated by P15

4.4.3.2.1.2 The estimates provided by P15

Figure 4.9 shows the estimates provided by P15. The notes below clarify why some of the values featured in Figure 4.9 are not written down in the actual questionnaire completed by P15 (which is included in Appendix C).

Notes about the estimates:

1. P15 estimated most likely values for the design cost, tender process cost and transaction costs. However, rather than estimating minimum and maximum values for each of these individual cost elements, P15 estimated the minimum and maximum values of the total sum of the design, tender and transaction costs. Therefore the minimum and maximum values of each these individual cost elements were derived by distributing the estimated total range between the three cost elements in proportion to the relative level of each cost element's most likely value.
2. P15 only specified the most likely values for CS 2. When asked to specify the minimum and maximum values, P15 stated that the minimum and maximum values for each element would cover the same percentage variation from the most likely value as the minimum and maximum values estimated for CS 1.

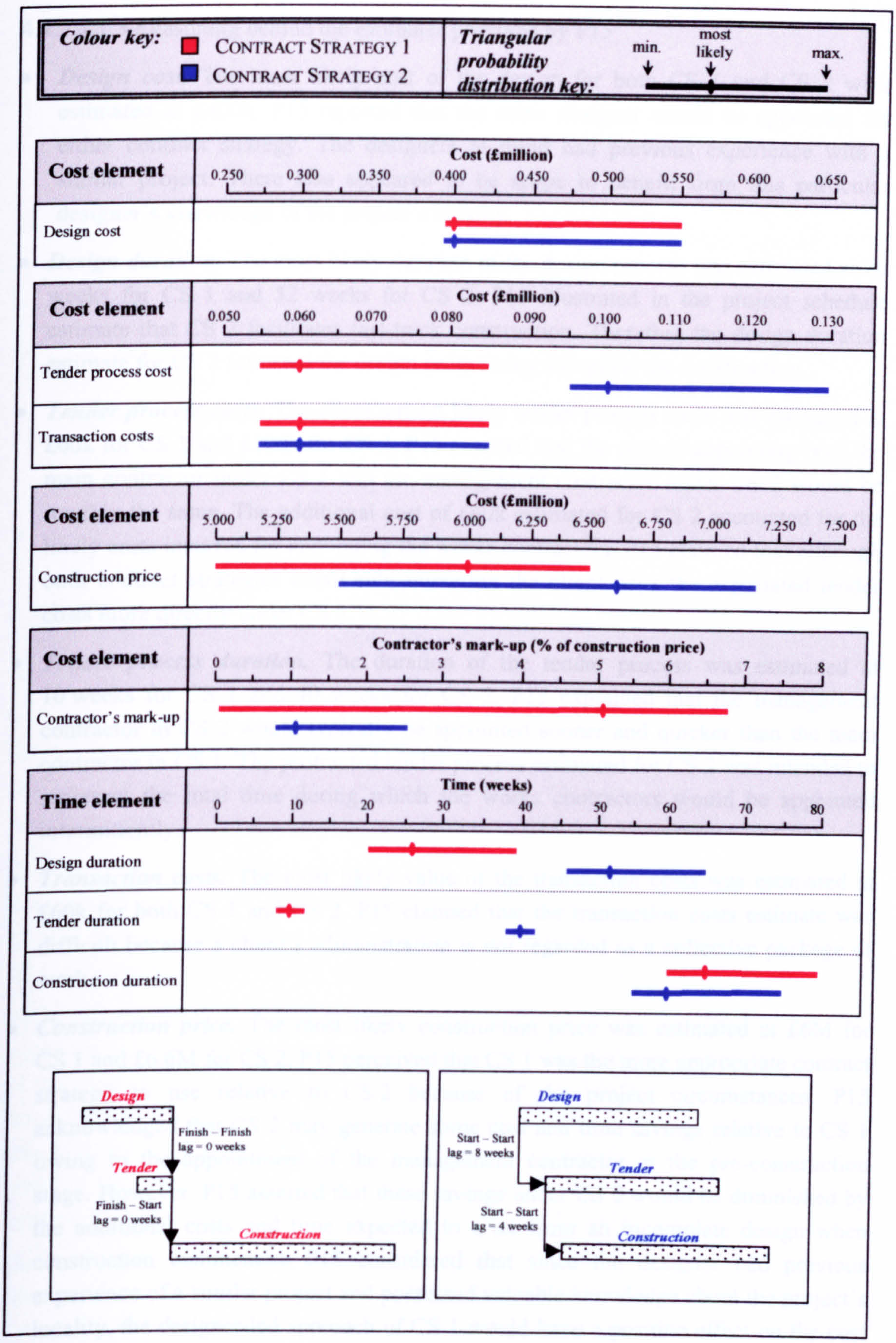


Figure 4.9 Questionnaire estimates provided by industrialist P15

4.4.3.2.1.3 Reasoning behind the estimates provided by P15

- *Design cost.* The most likely cost of the design for both CS 1 and CS 2 were estimated at £400k. P15 reported that the same designer would be appointed for either contract strategy. The designers in mind had previous experience with a similar project. There also appeared to be scope to benefit from this particular designer's knowledge of the project's locality.

- *Design duration.* The most likely duration of the design process was estimated at 26 weeks for CS 1 and 52 weeks for CS 2. P15 illustrated in the project schedule estimate that CS 2 facilitates fast-track construction. Therefore the design duration estimate for CS 2 reflected the design progressing alongside the construction.

- *Tender process costs.* The client's most likely tender process costs was estimated at £60k for CS 1 and £100k for CS 2. P15 asserted that the cost of appointing both the main contractor under CS 1 and the management contractor under CS 2 would be roughly the same. The additional cost of £40k estimated for CS 2 accounted for the likely costs incurred for appointing the works contractors. P15 claimed that although both contract strategies entail subcontracting the client pays the associated tender costs more directly under CS 2.

- *Tender process duration.* The duration of the tender process was estimated at 10 weeks for CS 1 and 40 weeks for CS 2. P15 explained that the management contractor in CS 2 would typically be appointed sooner and quicker than the main contractor in CS 1. The protracted tender process estimated for CS 2 was intended to represent the total time during which the works contractors would be appointed intermittently.

- *Transaction costs.* The most likely value of the transaction costs was estimated at £60k for both CS 1 and CS 2. P15 claimed that the transaction costs estimate was difficult because a client's administration is not regarded as a collective package of work.

- *Construction price.* The most likely construction price was estimated at £6M for CS 1 and £6.6M for CS 2. P15 perceived that CS 1 was the more appropriate contract strategy to use relative to CS 2 because of the project circumstances. P15 acknowledged that CS 2 may generate some cost and time savings relative to CS 1 owing to the appointment of the management contractor at the pre-construction stage. However, P15 asserted that these savings under CS 2 would be diminished by the additional costs and time expected to arise from an incomplete design when construction commences. P15 considered that since the designer had previous experience of a similar project and possessed valuable knowledge about the project's locality, the designer-led approach of CS 1 would have a positive effect on the cost and time performance of the project.

- ***Construction duration.*** The most likely duration of the construction process was estimated at 65 weeks for CS 1 and 60 weeks for CS 2. P15 specified during the project description that the project presented a difficulty with respect to site access. P15 perceived that if CS 2 was chosen to procure the project the management contractor appointed at the pre-construction stage was likely to suppress the site access problem and optimise the project plan. However, P15 asserted that the measures implemented by the management contractor to reduce the duration of the construction process relative to CS 1 would contribute to the higher construction price estimated for CS 2.
- ***Contractor's mark-up.*** The main contractor's most likely mark-up for CS 1 was estimated at 5% of the construction price. With regards CS 2, the management contractor's most likely fee was estimated at 1% of the construction price. P15 defended these estimates by claiming that, generally, CS 1 allocates more risk to the main contractor than CS 2 allocates to the management contractor.
- ***Project schedule.*** The most likely project duration was calculated at 101 weeks for CS 1 and 72 weeks for CS 2. P15 acknowledged that CS 2 would enable the construction to commence much earlier than CS 1 could. However, P15 reiterated that this was expected to hinder the execution of the project and give rise to additional costs.

4.4.3.2.1.4 The reaction of P15 to the calculated results

Figure 4.10 shows the results calculated from the estimates provided by P15. The results for each evaluated contract strategy are presented as a contour plot.

P15 indicated that the difference between the contract strategies' most likely price and duration values were as expected. However, P15 considered that the maximum duration of CS 1 displayed in Figure 4.10 was excessive. Nevertheless, following a review of the original estimates, P15 believed that his estimates were reasonable.

P15 made a number of references to the project's actual contract strategy decision. P15 explained that the client had prioritised the project quality and price requirements ahead of the time criterion. In addition, the client was prepared to pay a moderately higher price for CS 2 than CS 1 because the client perceived that the appointment of the management contractor under CS 2 would lead to a higher standard of quality. In contrast, P15 perceived that the designer-led approach of CS 1 was the better option because P15 considered that it would induce better quality and a lower price.

However, on reflection of the results, P15 appeared to be reconsidering which of the two contract strategies was the better option. P15 highlighted that although the client had not prioritised the time aspect of the project, the maximum project duration depicted in Figure 4.10 would have been deemed unacceptable. P15 was also unsettled that Figure 4.10 shows the maximum duration for CS 2 as being approximately the same as the minimum duration for CS 1.

P15 reviewed the original estimates again and declared that the two contract strategies' maximum time values estimated for each element should have received more attention. P15 declined to revise the estimates.

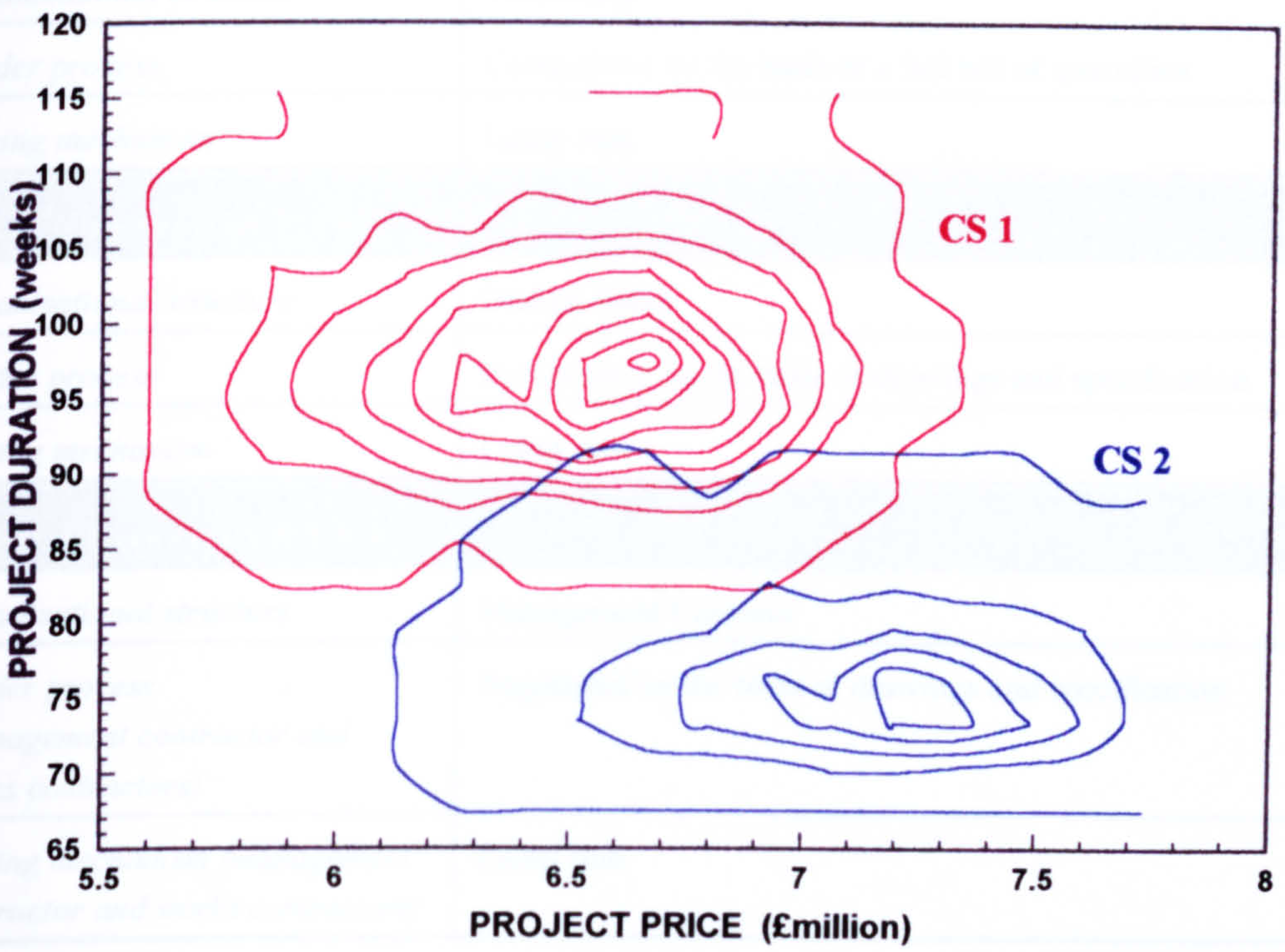


Figure 4.10 Results calculated from the estimates provided by P15

4.4.3.2.2 Questionnaire responses from the industrialists P4

The following sub-sections summarise the questionnaire responses from P4. A copy of the questionnaire completed by P4 is provided in Appendix C.

4.4.3.2.2.1 Description of the decision problem considered by P4

The project was described as a 30,000 square foot retail store. The building was built on a green-field site located in the centre of a city. The project was a one-off and P14 regarded the project as being of medium complexity. It was necessary to carry out enabling works to stabilise a cliff face (50 metres high) and embankment that surrounded the site.

The client was a property developer. The client had similarly developed an adjacent site ten years previous to this new project. Although the client had some construction experience, it had no in-house resources to directly contribute to the project.

The client stipulated medium standards with respect to the functionality of the building. The project brief was fixed by the occupier at the project outset.

Table 4.8 outlines details of the contract strategies evaluated by P4.

CONTRACT STRATEGY 1: CS 1	
Organisational structure	Traditional
Tender process	Competitive on the basis of a full bill of quantities
Pricing mechanism	Lump sum
CONTRACT STRATEGY 2: CS 2	
Organisational structure	Design-Build
Tender process	Competitive on the basis of drawings and specification
Pricing mechanism	Lump sum
CONTRACT STRATEGY 3: CS 3	
Organisational structure	Management Contract
Tender process (management contractor and works contractors)	Negotiated on the basis of drawings and specification
Pricing mechanism (management contractor and works contractors)	Lump sum

Table 4.8 The contract strategies chosen and evaluated by P4

4.4.3.2.2.2 Summary of the reasoning behind the estimates provided by P4

The actual values estimated by P4 can be found in Appendix C. This section outlines the key distinctions made between the evaluated contract strategies.

P4 considered that the project's design was relatively straightforward because of the type of project (i.e. retail unit). Therefore P4 claimed that the appointment of design consultants to both undertake and manage the design would be unnecessarily expensive and thus estimated the design cost under CS 1 at £25k higher than that estimated for CS 2 and CS 3.

P4 claimed that the cost of construction to the contractor would effectively be the same under all three contract strategies (£1M). However, he perceived the construction price would be the least under CS 1 and the highest under CS 3. This is because P4 asserted that CS 1 through to CS 3 allocated an increasing proportion of the project risk to the contractor. In the case of CS 3, P4 regarded the management contractor, rather than the works contractors, as being exposed to the bulk of project risk.

P4 estimated the contractor's average mark-up at 10%, 15% and 20% of the construction cost for CS 1, CS 2 and CS 3, respectively. P4 expressed that the mark-up estimates reflected his perception about each contract strategies' general division of risk between the client and contractor. He also claimed that the higher price values estimated for CS 3 reflected the fact that the construction and overall project was likely to be completed within a shorter period of time than if the other two contract strategies were used. In addition, P4 claimed that the project was too small to use CS 3.

4.4.3.2.2.3 The reaction of P4 to the calculated results

Figure 4.11 shows the results calculated from the estimates provided by P4. The results for each evaluated contract strategy are presented as a contour plot.

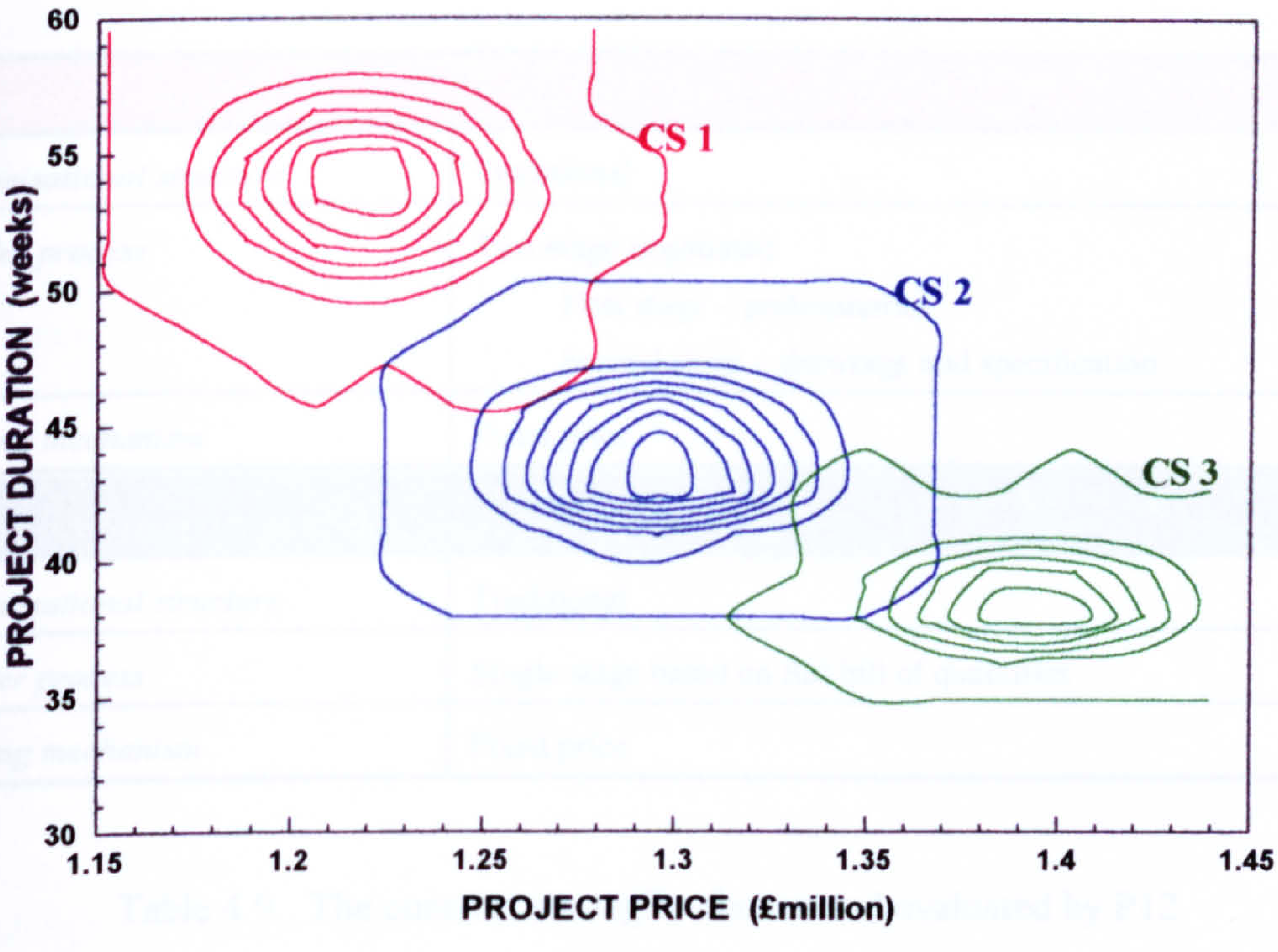


Figure 4.11 Results calculated from the estimates provided by P4

Basically, P4 expressed agreement with the results. He considered the results reflected quite accurately his perception about the differences between the three contract strategies that were evaluated. In addition, P4 conceded that his perceptions about the three contract strategies were generally applicable to most projects, not just the retail store development considered in this exercise.

4.4.3.2.3 Questionnaire responses from the industrialists P12

The following sub-sections summarise the questionnaire responses from P12. A copy of the questionnaire completed by P12 is provided in Appendix C.

4.4.3.2.3.1 Description of the decision problem considered by P12

The project was described as the fitting out of an airport lounge. It required an innovative, one-off design. P12 described the project as being of medium complexity and highlighted the fact that site-security was a very important requirement and hindrance.

The client had some construction experience and was very high profile. The client had in-house designers and project managers. The client stipulated high standards with respect to the functionality and aesthetics of the building. The project brief was fixed at the time of tender.

Table 4.9 outlines details of the contract strategies evaluated by P12.

CONTRACT STRATEGY 1: CS 1	
Organisational structure	Traditional
Tender process	Two-stage negotiated First stage – preliminaries Second stage – drawings and specification
Pricing mechanism	Fixed price
CONTRACT STRATEGY 2: CS 2	
Organisational structure	Traditional
Tender process	Single stage based on full bill of quantities
Pricing mechanism	Fixed price

Table 4.9 The contract strategies chosen and evaluated by P12

4.4.3.2.3.2 Summary of the reasoning behind the estimates provided by P12

The actual values estimated by P12 can be found in Appendix C. This section outlines the key distinctions made between the evaluated contract strategies.

P12 chose to evaluate two contract strategies where the only difference was the type of tender process employed for each contract strategy. P12 simply demonstrated that, for the project under consideration, a negotiated two-stage tender process could reduce the overall project duration because the tender process can take place whilst the design is ongoing.

4.4.3.2.3.3 The reaction of P12 to the calculated results

Figure 4.12 shows the results calculated from the estimates provided by P12. The results for each evaluated contract strategy are presented as a contour plot.

P12 said that the difference between the two contract strategies' most likely duration values appeared to be reasonable estimates

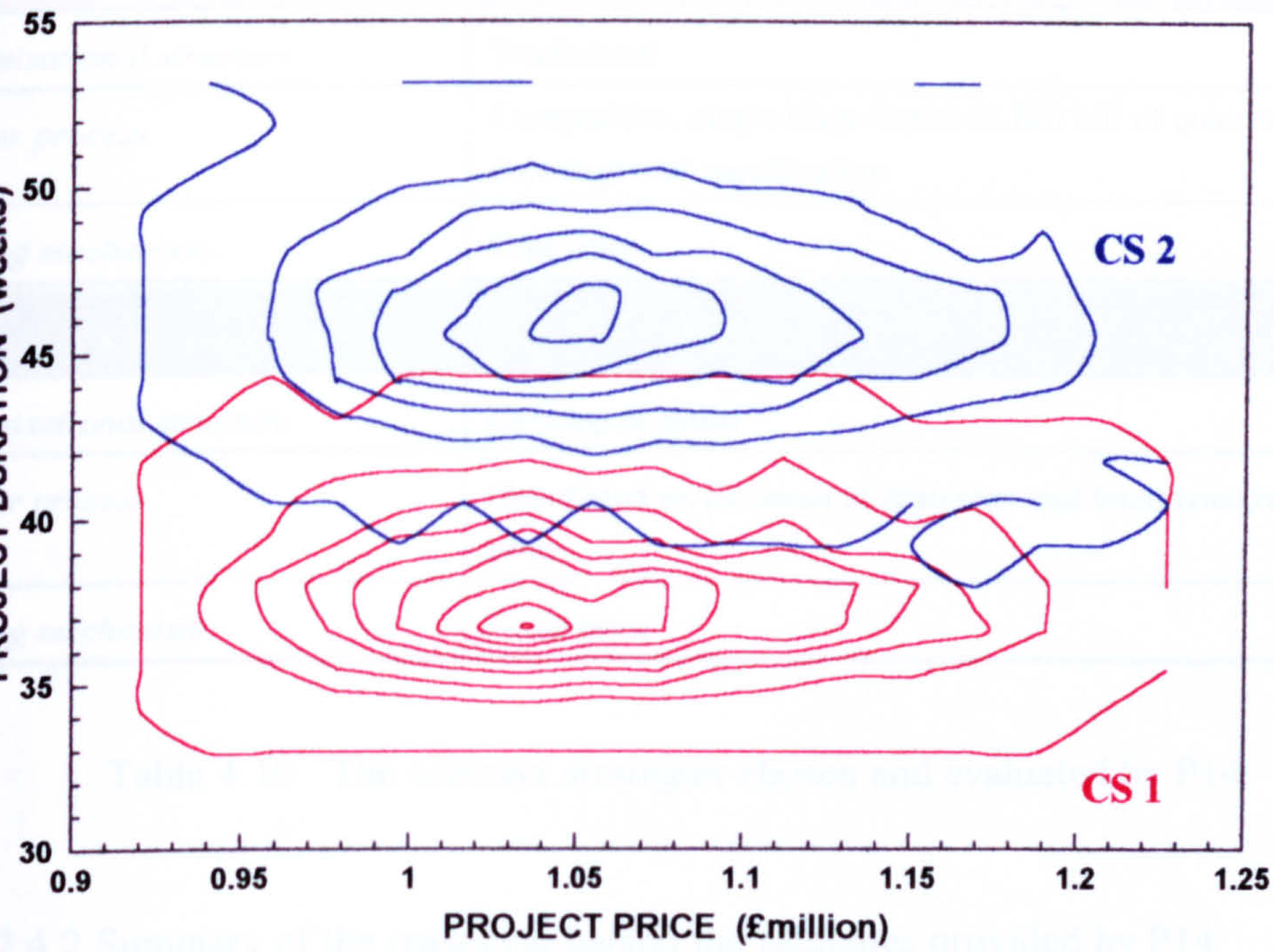


Figure 4.12 Results calculated from the estimates provided by P12

4.4.3.2.4 Questionnaire responses from the industrialists P14

The following sub-sections summarise the questionnaire responses from P14. A copy of the questionnaire completed by P14 is provided in Appendix C.

4.4.3.2.4.1 Description of the decision problem considered by P14

The project was described as a lift-footbridge over water. It was to be built on a fairly developed, but old, quayside close to a city centre. The project was a one-off and P14 claimed that the project was complex, especially its mechanical and electrical services. The conceptual design was the product of a design competition.

The client had limited construction experience. The client had its own in-house engineer and quantity surveyor. The client had a strict construction budget of £4.5M and was keen to transfer all risk to the construction contractor.

According to P14 the client had no intention to make changes once a construction contractor was appointed. The client stipulated high standards with respect to the functionality, durability and aesthetics of the bridge.

Table 4.10 outlines details of the contract strategies evaluated by P14.

CONTRACT STRATEGY 1: CS 1	
Organisational structure	Traditional
Tender process	Competitive, single stage based on full bill of quantities, drawings and specification
Pricing mechanism	Unit price
CONTRACT STRATEGY 2: CS 2	
Organisational structure	Develop & Build
Tender process	Negotiated on the basis of drawings and fixed construction price
Pricing mechanism	Fixed price

Table 4.10 The contract strategies chosen and evaluated by P14

4.4.3.2.4.2 Summary of the reasoning behind the estimates provided by P14

The actual values estimated by P14 can be found in Appendix C. This section outlines the key distinctions made between the evaluated contract strategies.

P14 estimated a higher design cost for CS 2. This is because P14 declared that the contractor's design services additional to the conceptual design consultants would result in a higher cost than if the design was undertaken solely by the design consultants. However, P14 asserted that the contractor's input into the design would lead to significant cost and time savings.

P14 claimed that the contractor's design contribution under CS 2 would ensure that the design was produced efficiently, and that the majority of construction risks would be "engineered-out" of the project. In other words, P14 expected the construction cost to be significantly less for CS 2 than CS 1. He estimated that the construction price under CS 2 would be £0.5M less than that under CS 1 and acknowledged that the estimated price for CS 2 included a larger mark-up than the price estimated for CS 1.

P14 estimated that the design would take 3 months less to complete under CS 2. In addition, P14 made reference to the facility of CS 2 to overlap design and construction when he estimated that the project would be completed within sixty percent of the project duration estimated for CS 1.

P14 acknowledged that under CS 2 the client required an agent to monitor the construction on behalf of the client. Subsequently P14 estimated £10k for the transaction costs under CS 1 and estimated £20k for the transaction costs under CS 2.

4.4.3.2.4.3 The reaction of P14 to the calculated results

Figure 4.13 shows the results calculated from the estimates provided by P14. The results for each evaluated contract strategy are presented as a contour plot.

P14 confirmed that the results provided an accurate representation of his perception about the differences between the two contract strategies for the considered project. P14 also expressed support for the explicitness of the results. He said that it would have been very helpful to have shown these results to the client of the project when the initial contract strategy-related decisions were made.

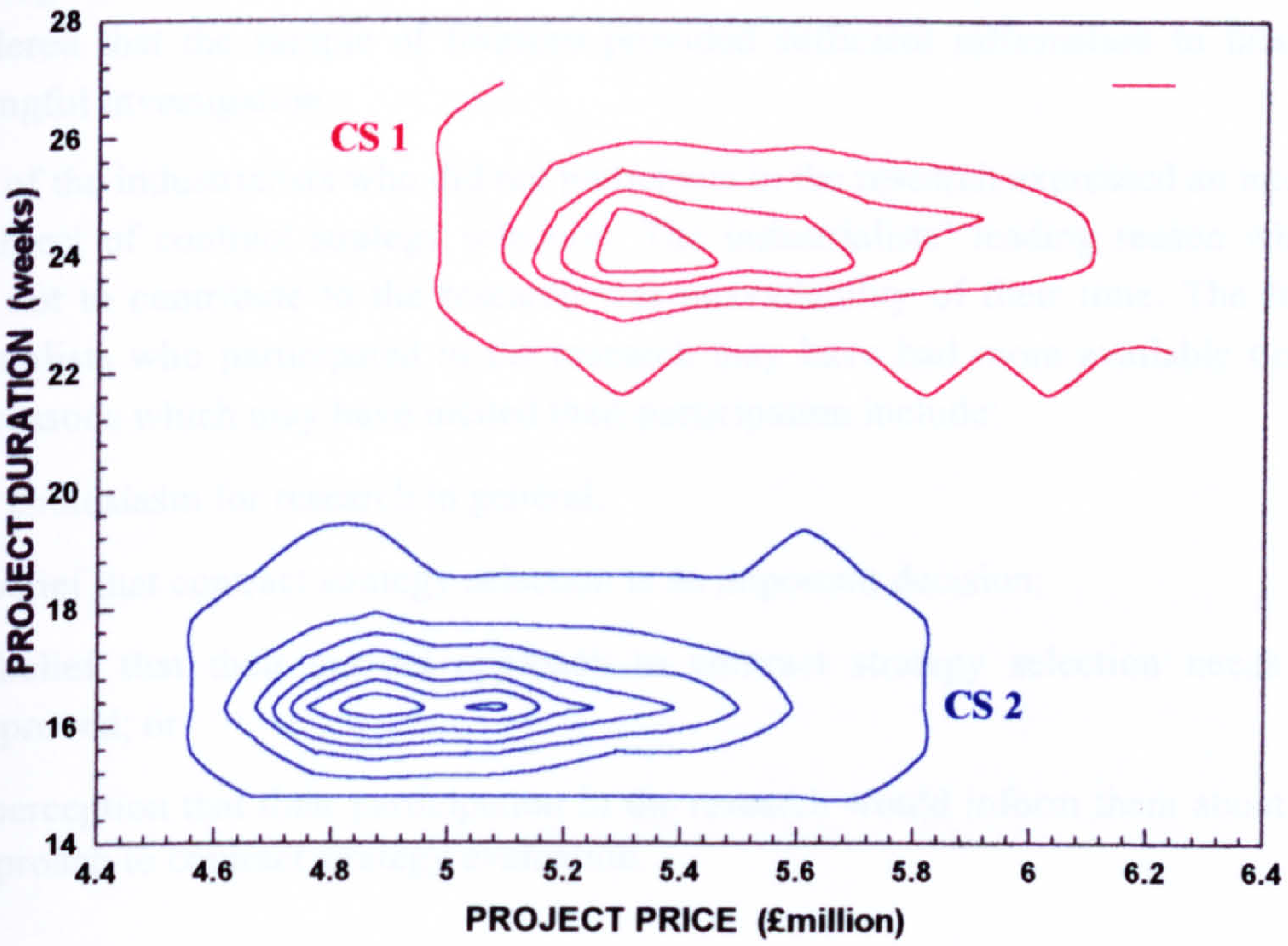


Figure 4.13 Results calculated from the estimates provided by P14

4.5 Discussion and conclusions of the empirical research

The empirical research set out to gain insights into the construction industry's typical approach to contract strategy evaluation and to obtain the views of industrialists on the feasibility and utility of the quantitative approach. This section summarises the key results of the empirical research. It offers explanations for certain results and discusses their implications for the feasibility and utility of the quantitative approach.

Section 4.5.1 briefly addresses the significance of the response-rate to the empirical research. Section 4.5.2 reviews the industrialists' ability to extend their normal practice to evaluate contract strategies quantitatively. Section 4.5.2 also highlights the data that indicated the capacity of the quantitative approach to aid contract strategy selection. Finally, section 4.5.3 focuses upon the insights gained from the empirical study that suggest how the research into the quantitative approach could develop.

4.5.1 The participants of the empirical research

Seventy five industrialists were asked to participate in the empirical research, of whom fourteen agreed to be interviewed. It was apparent from a relatively early stage that obtaining the views of a large sample of industrialists was not possible. However, it was considered that the sample of fourteen provided sufficient information to facilitate a meaningful investigation.

Many of the industrialists who did not participate in the research expressed an interest in the subject of contract strategy selection. The industrialists' leading reason why they chose not to contribute to the research was unavailability of their time. The fourteen industrialists who participated in the research may have had more available time, but other reasons which may have incited their participation include:

- an enthusiasm for research in general;
- a belief that contract strategy selection is an important decision;
- a belief that their current approach to contract strategy selection needs to be improved; or
- a perception that their participation in the research would inform them about a new approach to contract strategy evaluation.

4.5.2 The feasibility and utility of the quantitative approach

The feasibility and utility of the quantitative approach is examined in relation to several issues. Section 4.5.2.1 discusses the industrialists' ability to differentiate between contract strategies in terms of their probable cost and time effects. Perceptions about the practical implications of the quantitative approach are presented in section 4.5.2.2. Section 4.5.2.3 reviews the reasoning used by the questionnaire respondents to justify their quantitative estimates. Empirical research results that support the decision-aid capabilities of the quantitative approach are the subject of section 4.5.2.4.

4.5.2.1 Differentiation between contract strategies in terms of cost and time

All of the industrialists believed that different contract strategies could have different impacts upon the price and duration of a project. Some of the industrialists reported that they had experience of making quantitative estimates of contract strategies' potential impacts upon the overall project price and duration. During the interviews, the majority of the industrialists claimed that that they could estimate, both qualitatively and quantitatively, the impact that a contract strategy's general division of risk and facility to fast-track was likely to have on a project's overall price and duration. However, it was evident that none had previously estimated, quantitatively, contract strategies' potential impacts upon a series of cost and time elements which cumulated to the project price and duration.

It appeared that the industrialists' evaluation of contract strategies would typically comprise subjective assumptions which made express reference to contract strategies' probable cost and time effects. However, their evaluation processes also comprised assumptions which made reference to criteria other than cost and time. These other criteria related to project circumstance (e.g. project size, project complexity, client type, market conditions, availability of particular contractors, etc.). Despite this wide variety of decision criteria, all of the industrialists recognised that the ultimate aim of contract strategy selection was to enable the achievement of the client's primary objectives (i.e. price, time and quality targets).

Although the empirical study provided evidence to suggest that contract strategy evaluation can be undertaken in the context of cost and time effects, all of the industrialists expressed concerns about the uncertainty surrounding highly-intuitive qualitative and quantitative estimates of contract strategies' probable cost and time effects. There was a fairly common view that many of the issues addressed during contract strategy evaluation cannot be expressed in the qualitative context of cost and time effects. This view could suggest that subjective assumptions about contract strategies are not always rationalised in terms of the client's primary objectives (one of the deficiencies perceived to exist in the industry's typical approach to contract strategy selection - see section 2.3.2).

During the course of the empirical study, several industrialists' concerns about uncertainty appeared to have been eased because they demonstrated that they were quite-readily prepared to make qualitative estimates about contract strategies' probable cost and time effects. Some of the industrialists stated outright that many of their subjective assumptions about contract strategies which make reference to decision criteria, other than cost and time, could be interpreted as having cost and time implications. Meanwhile, other industrialists provided example applications of this theory. For example, a large number of the industrialists claimed that the appropriateness of a contract strategy, in the light of a particular client, can be referred to in terms of a positive or negative effect upon the project's price and duration. In addition, four of the six industrialists who completed questionnaires estimated cost and time values that accounted for the potential effect of appointing a contractor during the early stages of a project.

Although, effectively, all fourteen industrialists expressed some reservations about the feasibility of the quantitative approach, a few appreciated that the approach aimed to impose order into their current evaluation process. None of the industrialists openly expressed concerns about their current approach to contract strategy evaluation. However, three industrialists who initially offered dissenting views eventually became more in favour of the quantitative approach as they became more familiar with its principles. These three industrialists, together with four others, provided some positive appraisal of the quantitative approach. The fact that six out of these seven industrialists completed questionnaires indicated that they had understood the quantitative approach and thus provided informed views about its feasibility and utility.

The industrialists who completed questionnaires demonstrated that they could translate subjective assumptions about contract strategies into quantitative estimates of contract strategies' potential cost and time effects. It is important, however, to recognise that the questionnaires could only aim to provide a very basic simulation of an actual contract strategy selection process at the outset of a project.

It has already been acknowledged that all fourteen industrialists interviewed indicated that they perceived different contract strategies could have different impacts on the price and duration of projects. The graphical presentations of the results calculated from the six industrialists' questionnaire estimates (section 4.4.3) illustrate that different contract strategies can be expected to have significantly different impacts upon the price and duration of projects. For example, the results calculated from the questionnaire estimates provided by P10 show that the project price under the Management Contract type contract strategy could be a maximum of 24% more than the price for the same project under the Design-Build type contract strategy (see Figure 4.6).

The questionnaires required the industrialists to estimate contract strategies' impacts upon a set of cost and time elements which cumulate to the project price and duration (e.g. design cost and duration, tender process costs and duration, etc.). Therefore the six industrialists who completed questionnaires demonstrated that they could discern which aspects of a project were likely to be affected by a contract strategy. The completed questionnaires also indicated that, in a given contract strategy decision problem, different contract strategies could be evaluated consistently against the same set of criteria (i.e. the effects that different contract strategies are likely to have on the same set of cost and time elements).

4.5.2.2 Practicality of the quantitative approach

The industrialists indicated that their normal approach to contract strategy evaluation relies upon intuitive decision logic. They focus upon issues that are identified, intuitively, as the most important issues in the decision problem presented by each project. Some of the industrialists also appeared to attach little importance to contract strategy decisions made at the outset of projects. They claimed that these decisions, typically, did not have as much impact on a project as those decisions made at later project stages (e.g. allocation of particular risks, which organisations to appoint as construction contractors). These industrialists acknowledged that a contract strategy was a compilation of components. However, they apparently perceived the interrelationship between the components did not warrant consideration when the early contract strategy decisions were made.

Many of the industrialists claimed that their current approach to contract strategy evaluation was more efficient than the quantitative approach. Some of the industrialists asserted that their evaluation processes had to be efficient owing to the time and money constraints, particularly prevalent at the outset of projects. In contrast, some industrialists recognised the need for improvement in the quality of decisions made at the project outset. They perceived this would ensure projects were managed more efficiently.

The insights gained into the industrialists' current approach to contract strategy evaluation indicated that they reduced the potential intricacy of the process to a level which they considered was manageable and led to satisfactory decisions. However, the following section reports that the six questionnaire respondents provided evidence to support the perception that numerous deficiencies are inherent in the industry's typical approach to contract strategy selection (see section 2.3.2).

4.5.2.3 Rationalisation of contract strategy evaluation

The industrialists who completed questionnaires were asked to justify the cost and time values that they estimated. These estimate-justifications provided a further indication of the feasibility and utility of the quantitative approach. They also provided valuable insights into the industrialists' current approach to contract strategy evaluation.

All six industrialists provided a reason to explain all instances where they had estimated different cost and time levels for different contract strategies. The reasons given explained why they perceived each contract strategy was likely to have a particular type of effect on the cost and time elements (i.e. whether one contract strategy was likely to induce a saving or loss relative to another contract strategy). However, the industrialists did not explain why they perceived each contract strategy was likely to have a particular level of effect on the cost and time elements (i.e. what size of saving or loss was likely to be made). For example, P16 claimed that the design cost for the office building project presented in Questionnaire 1B would be less under a Design-Build type contract strategy than a Traditional type contract strategy because having the same party design and build the project reduces the amount of detailed design. He did not, however, explain why the estimated range of design cost values for the Design-Build type contract strategy were specifically £40k lower than the range estimated for the Traditional type contract strategy.

The questionnaire responses from industrialist P15 included a claim that cost and time savings could be attained if a specific design organisation was appointed under a particular contract strategy. However, there were very few other estimate-justifications that accounted for a project's particular circumstances. Rather than addressing the specific details of each contract strategy and project's circumstances, it appeared that the estimate-justifications were dominated by general perceptions about broad types of contract strategies. In fact, P4 acknowledged that the justifications for his estimates applied to the same contract strategy types on most projects, not just the project considered for the questionnaire.

There was a suspicion that the industrialists may associate the particular details of standard contract forms with their respective organisational structure labels, and vice versa. In other words, it appeared that the industrialists might have a tendency to categorise their knowledge about contract strategies under very broad headings such as Traditional, Design-Build and Management Contracting.

This theory was supported by the virtually consistent ranking order between the mean project price and duration calculated for the contract strategies that classify under the categories of Traditional, Design-Build and Management Contracting. The general trends observed between the results calculated from five of the industrialists' questionnaire responses were:

1. the contract strategies' mean project price in the following ascending order: Design-Build, Traditional and Management Contract; and
2. the contract strategies' mean project duration in the following ascending order: Management Contract, Design-Build and Traditional.

The consistency between the five sets of results was compounded by the relative agreement between the industrialists' estimate-justifications for each contract strategy type. For example, all five industrialists recognised that the project duration was primarily dependent upon whether the contract strategy facilitates fast-track construction. In addition, several of the industrialists made some reference to the potential cost and time savings which can ensue from the early involvement of a contractor. The industrialists also had similar views on the subject of risk allocation and contractors' mark-up levels for each contract strategy that classifies under the Traditional, Design-Build and Management Contract categories. It appeared that the industrialists interpreted a contract strategy's general division of risk between the client and main contracting party from the contract strategy's general organisational structure label and, to a lesser extent, from the pricing mechanism type used to remunerate the principal contractor.

Assuming that the industrialists have a tendency to relate to broadly-defined contract strategy types and thereby do not evaluate contract strategies at a particularly detailed level, it may be inferred that the industrialists select contract strategies from a very limited range of options. Section 2.3.2 reported that the industry's approach to contract strategy selection was defective in that a decision-maker, typically, has a limited appreciation of plausible decision options when selecting a contract strategy.

It is important to remain aware that the primary purpose of the questionnaires was for industrialists to translate their subjective distinctions between contract strategies into cost and time estimates. It was appreciated that the questionnaires did not constitute an ideal test of whether quantitative estimates of contract strategies' potential cost and time impacts on a project would be rationalised as much as possible. For example, the two industrialists who completed Questionnaire 1B displayed difficulties in relating to the hypothetical office building project. This was expected since the questionnaires could only provide a relatively small amount of information about the project. Questionnaire 2 was designed to overcome this disadvantage of Questionnaire 1B. However, because the respondents of Questionnaire 2 were permitted to consider a project which they had previously been involved with, it was probable that their estimates and reasoning were influenced by actual project events.

The industrialists' reference to broad contract strategy types and failure to account for the case-specifics of each decision problem could be attributed to the limitations of the questionnaires. Alternatively, the estimate-justifications may be considered to represent the industrialists' typical approach to contract strategy selection. Imprecise and generally-applicable decision logic were reported in section 2.3.2 as deficiencies perceived to be inherent in the industry's typical approach to contract strategy selection.

The industrialists' estimate-justifications also indicated the existence of another deficiency in the industry's typical approach to contract strategy selection - failure to rationalise decision uncertainty (see section 2.3.2). The six industrialists who completed questionnaires gave little explanation as to why they had estimated the specific range for each cost and time element. All six industrialists made some attempt to account for the possible range of values that each cost and time element may assume without acknowledging which specific events could bring about the values within the estimated range. For example, P16 did not explain why the design cost could be as low as £660k and as high as £810k if the Design-Build type contract strategy was used on the office building project.

One may attribute this last observation again to the limitations of the questionnaires, but it may also be attributed to the industrialists' failure to understand, and appreciate the relevance of, probabilistic techniques. Four of the six industrialists (P4, P10, P12 and P16) estimated minimum, most likely and maximum values for all of the cost and time elements, but it was apparent that only two of these industrialists (P4 and P16) appreciated the relevance of this technique. Two of the six industrialists (P14 and P15) did not estimate the minimum, most likely and maximum values for all of the cost and time elements. Instead they focused upon the most likely value. When prompted to estimate the minimum and maximum values, both P14 and P15 estimated some of these values in terms of a percentage decrease and increase relative to the most likely value.

4.5.2.4 Decision aid provided by the quantitative approach

Two of the interviewed industrialists stated that the quantitative approach served a useful purpose in breaking contract strategy selection down into a series of sub-decisions where each sub-decision was an appraisal of a contract strategy with respect to a project's specific cost and time element (e.g. design cost, tender process duration, etc.). This appeared to suggest that their current approach to contract strategy selection was unstructured.

Four industrialists commended the quantitative approach for its focus upon contract strategy decisions made at the outset of projects. These industrialists regarded good, early project decisions as prerequisites for a successfully-managed project.

Many of the industrialists showed particular interest in the set of results from an example application of the quantitative approach. They recognised the value in the explicitness of the results. Ten of the fourteen industrialists made favourable references about the overview of the likely differences between contract strategies which the results provided.

It was suspected that some of the industrialists would have been disappointed by the fact that the results attained from an application of the quantitative approach do not express, outright, which contract strategy is the best option to select. Surprisingly, only one industrialist made reference to this point. However, seven industrialists revealed reservations about the value of the results. The industrialists were aware that the results were obtained by the accumulation of a contract strategist's estimates. Hence these seven industrialists were perturbed that any results of the quantitative approach would simply reflect, and even magnify, the high level of uncertainty and subjectivity in the contract strategist's estimates.

This last response suggests that some of the industrialists did not perceive that the process involved in arriving at the results would provide any benefit to the decision process. Several industrialists refuted the attempts of the quantitative approach to improve their understanding of the impacts that contract strategies have on projects. Some claimed that a high level of uncertainty and subjectivity would always surround contract strategy selection because every new project presents a different decision problem. However, two of the six industrialists who completed questionnaires demonstrated some of the potential of the quantitative approach to aid the decision process.

When the industrialists P15 and P16 were shown the results calculated from their own questionnaire estimates, their reactions revealed that they had not fully appreciated the implications that their estimates of individual project elements would have on the overall project price and duration results. P15 claimed that the maximum project duration value calculated for one of the evaluated contract strategies was too high (see Figure 4.10). The project under consideration was one that P15 had been involved in. Effectively, he acknowledged that the information about the contract strategy's most pessimistic impact on the project's duration, had it been explicitly evaluated at the time, may have influenced the actual contract strategy selection process (section 4.4.3.2.1.4). Meanwhile, P16 experienced a similar enlightenment when shown the results calculated from his own estimates (see Figure 4.8). P16 believed that the difference between the mean project price for two of the contract strategies evaluated should differ from that presented in the results (section 4.4.3.1.2.3).

Therefore one may interpret these two industrialists' reactions to their results as an indication that an elemental breakdown of the evaluation process can provide different, and possibly more valuable, insights to assist the decision process than an all-encompassing intuitive evaluation. Furthermore, it is important to note that the industrialists' recognition of these discrepancies between their intuition, before and after reviewing their results, would not have been possible if the evaluation process had not been as explicit as that demanded by the quantitative approach.

It may be concluded that the combined process of applying the quantitative approach and the subsequent review of the estimates can make the decision-maker more aware of the significance of their estimates. Therefore one would expect this in turn to motivate contract strategy selectors to rationalise their estimates as much as possible.

4.5.3 Implications of the empirical research to the prototype model

The empirical research confirmed that the quantitative approach is different from the industry's current approach to contract strategy evaluation. There were signs that this difference was perceived by the industrialists as too great to overcome. Although the questionnaire respondents demonstrated an ability to adapt their current approach to contract strategy evaluation to a quantitative evaluation, many of the deficiencies associated with contract strategy selection practice were not eliminated by the application of the quantitative approach (section 4.5.2.3).

The questionnaires required the quantitative approach to be applied in the same format as the prototype model (described in Chapter 3). As a result, it appeared necessary to review the design of the prototype model.

Section 4.5.2.3 reported that the questionnaire respondents estimated cost and time values that accounted for their generally-applicable perceptions about broadly-defined contract strategy types (e.g. Traditional, Design-Build). Virtually no express reference was made to the particular circumstances of the respective projects. Therefore the design of the prototype model had to be reviewed with respect to:

- precision with which contract strategies were defined and simulated by the model; and
- addressing the specific circumstances of each contract strategy decision problem.

Sections 4.4.2.5.2 and 4.5.2.3 indicated that the majority of the industrialists did not fully understand the concept of probability distribution estimates. It was suspected that this quantification method was too abstract because in each triangular probability distribution estimate a decision-maker was required to account for the uncertainty inherent in the cost/time element as well as reflect the potential impact of the particular contract strategy under evaluation. Therefore it appeared appropriate to examine means of making the quantification process more intuitive to a contract strategy decision-maker.

A number of design compromises were made when the prototype model was developed. Some of these design compromises coincided with the model limitations highlighted by the empirical research. Following an assessment of the prototype model, the results of the empirical research and the nature of the contract strategy decision problem, it was decided to design a new model. The refined model facilitates the application of a quantitative approach to contract strategy evaluation in a different format to that facilitated by the prototype model. The next chapter describes the refinements made to the prototype model.

5. Model Refinements

Chapter 3 described the prototype model designed to facilitate the application of a quantitative approach to contract strategy evaluation. This model was evaluated both academically (for example, see section 3.3.3) and, through an empirical study, by industrialists (see section 4.4). There were indications that the quantitative approach embodied within the prototype model was valid and useful.

Since it was perceived important to establish, demonstrate and test the principles of the quantitative approach, several design compromises were made during the development of the prototype model. The major limitations of the model included:

- inflexibility with respect to the contract strategies that can be simulated and thus evaluated;
- imprecision in the definition and simulation of contract strategy options;
- inflexibility owing to constraints on the number of activities which may be used to simulate a project;
- the uncertainty inherent in each cost and time element has to be implicitly accounted for in the triangular probability distribution estimates;
- in each model simulation there is no correlation between the calculated values of project price and project duration; and
- there is no facility to account for dependencies between the individual cost and time elements.

The decision to refine the model was based upon the findings of the preceding research into the quantitative approach to contract strategy evaluation. Reference to these research findings was again required in order to:

1. identify which limitations of the prototype model were critical to the validity and usability of the model; and
2. design the simulation techniques to enable the necessary refinements to be incorporated.

The first of these steps in upgrading the model involved consideration of the general philosophy of a quantitative approach to contract strategy evaluation. The following types of questions were addressed:

- Which general contract strategy features ought the model be able to recognise and/or simulate?
- Which cost and time elements should be quantified?
- Is it possible to aid the decision-maker estimate more accurate inputs?

- Should the model's computations produce a more realistic output (e.g. correlation between cost and time)?
- Are there model outputs, in addition to project price and duration, that are relevant to, and useful for, contract strategy selection?

The following sections of this chapter describe the simulation techniques which were incorporated into the refined model. These techniques were used to obtain the results from the example model applications featured in Chapter 6. Furthermore, the following descriptions also address the strategic questions posed above.

Figure 5.1 provides a simplified breakdown of the model inputs required for each contract strategy evaluated in an application of the refined model. A more detailed list of the model inputs is provided at the end of the chapter. It should also be noted that a copy of the refined model is provided in Appendix D.

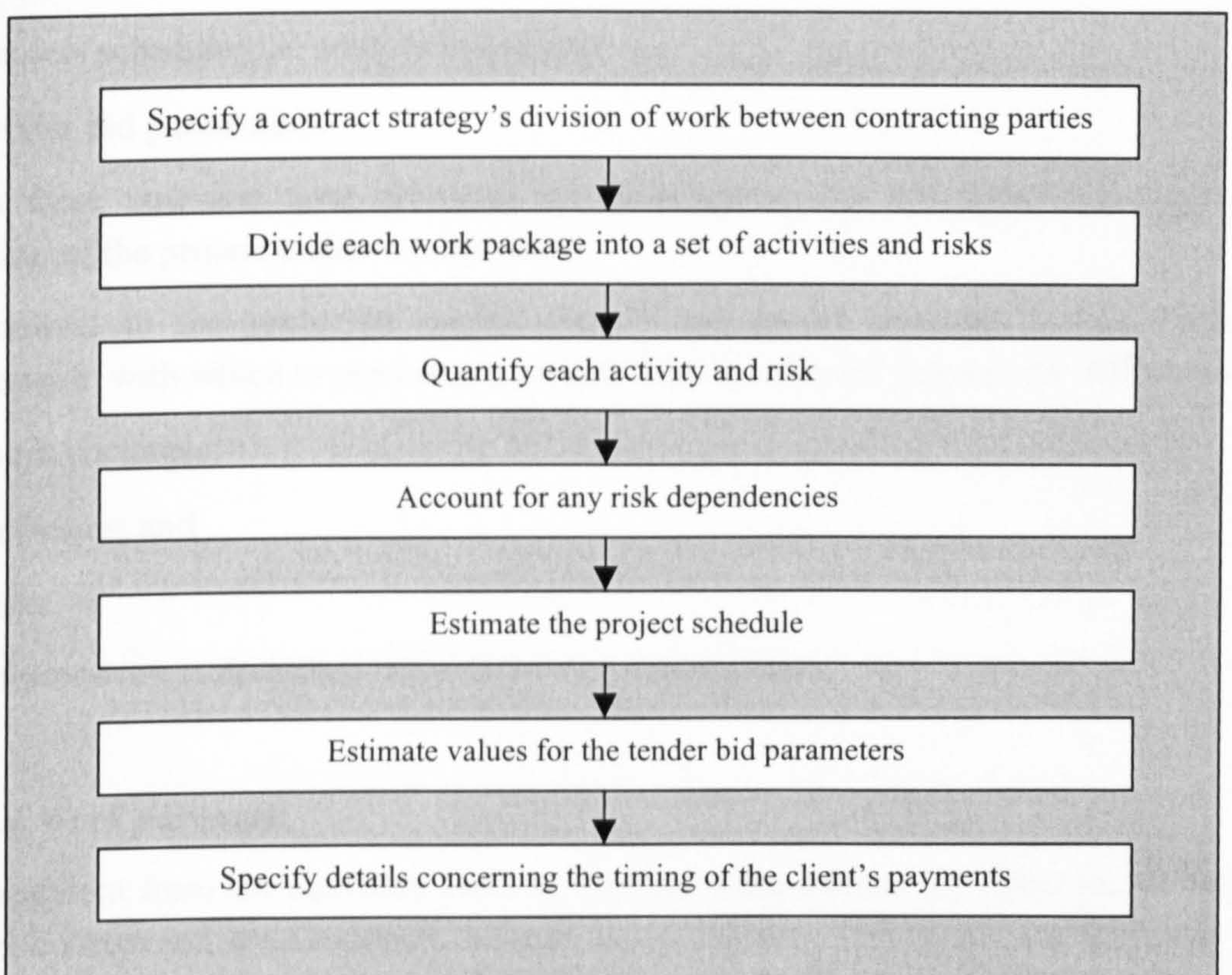


Figure 5.1 Seven steps of model inputs for each evaluated contract strategy

5.1 Simulation of project performance

As with the prototype model, the refined model simulates the cost and time performance of projects. The refined model was designed to provide a flexible framework with which to attain a more sophisticated representation of a project than that attainable in the application of the prototype model. The type and format of model inputs have been designed to assist the user and are also intended to produce additional model output to that of the prototype model.

5.1.1 Elemental breakdown of projects

In the prototype model a project was divided into the following activities:

- design activity;
- tender process activity; and
- up to a maximum of four construction activities.

The model-user was required to estimate the cost and duration of each of the above project activities. The user was also required to estimate values for the following:

- transaction costs;
- project schedule (i.e. activity links); and
- tender bid parameters.

From these cost and time estimates the prototype model calculated the price and duration of the project under consideration.

In contrast to the prototype model, the refined model provides a more flexible framework with which to represent a project. This is achieved through the definition of:

- work packages;
- activities; and
- risks.

This framework is described in the following sub-sections.

5.1.1.1 Work packages

It is apparent from the activities listed at the beginning section 5.1.1 that the prototype model constrained the elemental breakdown of projects. The obligation to model the design activity as a single activity was considered to be a severe restriction. However, this restriction was justified because it was decided to provide a framework to simulate just three contract strategies within the prototype model (see section 3.3.2.2). Section 5.2.1 indicates that in order to simulate a wider variety of contract strategy options, the model must provide a more flexible framework with which to specify and simulate the constituent elements of a project.

The model was refined to enable each evaluated contract strategy to be represented as a series of work packages. Essentially, each work package includes a set of activities that are to be assigned to a particular party. Section 5.2.1 reports the versatility of this facility.

5.1.1.2 Project activities

The model was designed to enable the user to specify any number and type of project activities within each work package. Therefore, for example, it is possible to model a project's design process as a series of activities, each of which may be undertaken by a different party.

In contrast to the prototype model, it was decided not to include transaction costs as an explicit cost element in the refined model. This decision was governed by the perception that the new flexible framework, with which a project can be simulated, enables the user to specifically account for the issues which are expected to influence transaction costs in the relevant activities' cost estimates.

5.1.1.3 Project risks

In the prototype model the user was required to estimate a triangular probability distribution of values (i.e. minimum, most likely and maximum values) for each cost and time element. Each distribution estimate was intended to account for the uncertainty generated by the risk(s) related to the cost/time element.

Section 4.5.2.3 reported that the majority of industrialists who completed questionnaires, performed a generalised and imprecise evaluation of each contract strategy's risk allocation. They appeared to interpret a contract strategy's general division of risk between the client and main contracting party from the contract strategy's general organisational structure label and, to a lesser extent, from the pricing mechanism type used to remunerate the principal contractor.

It was decided that a model that facilitated an explicit risk analysis was likely to aid the decision-maker on two levels:

- more precise definition of each evaluated contract strategy; and
- a greater account of each project's circumstances.

The remainder of this section describes the risk identification stage while the subsequent section describes the method designed to model and analyse project risks.

The preceding section reported that the model-user is able to specify any number and type of project activities in an application of the refined model. Once the activities are specified, the user is prompted to identify the risk, or risks, related to each activity. There is an option to either specify and analyse the general risk associated with an activity or specify and analyse more than one specific risk related to an activity. For example, consider the activity 'substructure construction', Table 5.1 presents two alternative ways of representing the risk related to this activity. The user may opt to model the risk related to the activity as a whole (i.e. Option 1 in Table 5.1). Alternatively, the user may opt to model the risk related to the activity as two specific risks (i.e. Option 2 in Table 5.1).

	Risk specified for 'substructure construction' activity
Option 1	General activity risk
Option 2	Specific Risk 1: unforeseen ground conditions Specific Risk 2: unavailable plant

Table 5.1 Alternative ways of specifying the risk related to the example activity 'substructure construction'

When identifying which risks to analyse it is important to separate risks that are allocable to different parties. This is to enable the model to analyse the effect of a contract strategy's risk allocation. Therefore in the above example, if the client is responsible for the risk of 'unforeseen ground conditions' and the contractor is responsible for the risk of 'unavailable plant', the user should model the specific risks, as opposed to the general risk. Section 5.2.2 provides further details about the model's capacity to simulate a contract strategy's risk allocation.

5.1.2 Quantification of project activities and risks

In the prototype model the majority of cost and time elements were activities. Therefore the model-user was required to estimate a triangular probability distribution of values (i.e. minimum, most likely and maximum values) for the cost and duration of a series of activities.

Sections 4.4.2.5.2 and 4.5.2.3 indicated that the majority of the industrialists did not fully understand the concept of probability distribution estimates. The six questionnaire respondents were unable to explain precisely why each cost and time element could assume the values within the range they had estimated.

It was inferred that the concept of triangular probability distribution estimates was too abstract to mitigate the industrialists' reluctance to appreciate the relevance of accounting for a project's cost and time uncertainty. Furthermore, the preceding section highlighted the fact that this quantification method inhibits an explicit risk analysis. As a result, it was concluded that the quantification process was likely to become more intuitive if it constituted a risk analysis.

A further limitation of the quantification method adopted by the prototype model (i.e. triangular probability distributions) was its failure to simulate the time-cost relationship of each activity. In an application of the prototype model it would be probable that the user's cost and time distribution estimates for each activity would reflect an implied time-cost relationship for the activity. For example, the occurrence of a risk event that causes a high estimated cost is likely to result in a correspondingly high value of the same activity's estimated duration.

However, in the prototype model the activities' implied time-cost relationships were not accounted for in the calculation process. This is because the model was designed to randomly sample values from each cost and time distribution in each simulated run of a project. Consequently, in each simulation, the cost of an activity was independent of the activity's duration. It follows, therefore, that each simulated project price was independent of the simulated project duration.

It was decided to design a quantification method that:

- assisted the user to model the time-cost relationship of each risk and thus each activity; and
- ensured that an activity's simulated cost realistically correlates with its simulated duration.

The quantification process designed for the refined model requires the user to estimate a 'base cost' and 'base duration' for each activity. These values are intended to reflect the cost and duration of the activity assuming the activity is not exposed to any risk. The model-user is then required to estimate a set of additional cost and delay values associated with each risk related to an activity.

A risk's additional cost and delay values are normalised against the same risk scale. The risk scale is calibrated in units of 'percentage of maximum risk level occurrence'. Therefore the risk scale ranges from 0% of the maximum risk level occurrence to 100% of the maximum risk level occurrence. The scale is divided into four quartile levels and each level has been assigned a qualitative label that makes reference to a relative scale of consequence (see Table 5.2). The particular labels displayed in Table 5.2 may be considered to relate solely to major project risks. When quantifying risks, the user must interpret the quartile levels as appropriate.

For each individual risk, the model-user is prompted to estimate an additional cost value and delay value at each quarterly risk level. The user is then required to estimate which of the five quarterly risk levels is the most likely level to be assumed by the risk in question. This single estimate defines a triangular probability distribution that dictates the likelihood that the risk will assume any level ranging from 0% to 100% of the maximum risk level occurrence. Figure 5.2a shows an example triangular probability distribution for the risk level. Figures 5.2b and 5.2c are example graphical representations of a set of additional cost and delay values estimated for a particular risk.

% of max. risk level occurrence	Degree of occurrence
0%	Negligible
25%	Marginal
50%	Serious
75%	Severe
100%	Critical

Table 5.2 The quantitative and qualitative quarterly measures of risk level

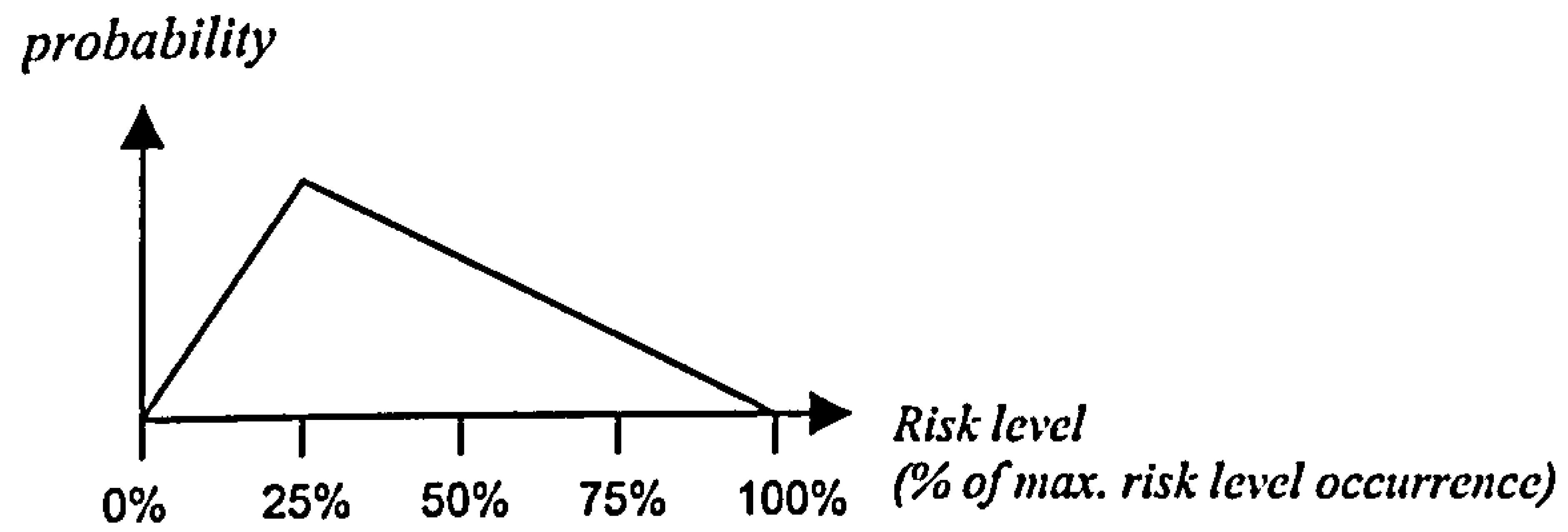


Figure 5.2a

Probability distribution of risk

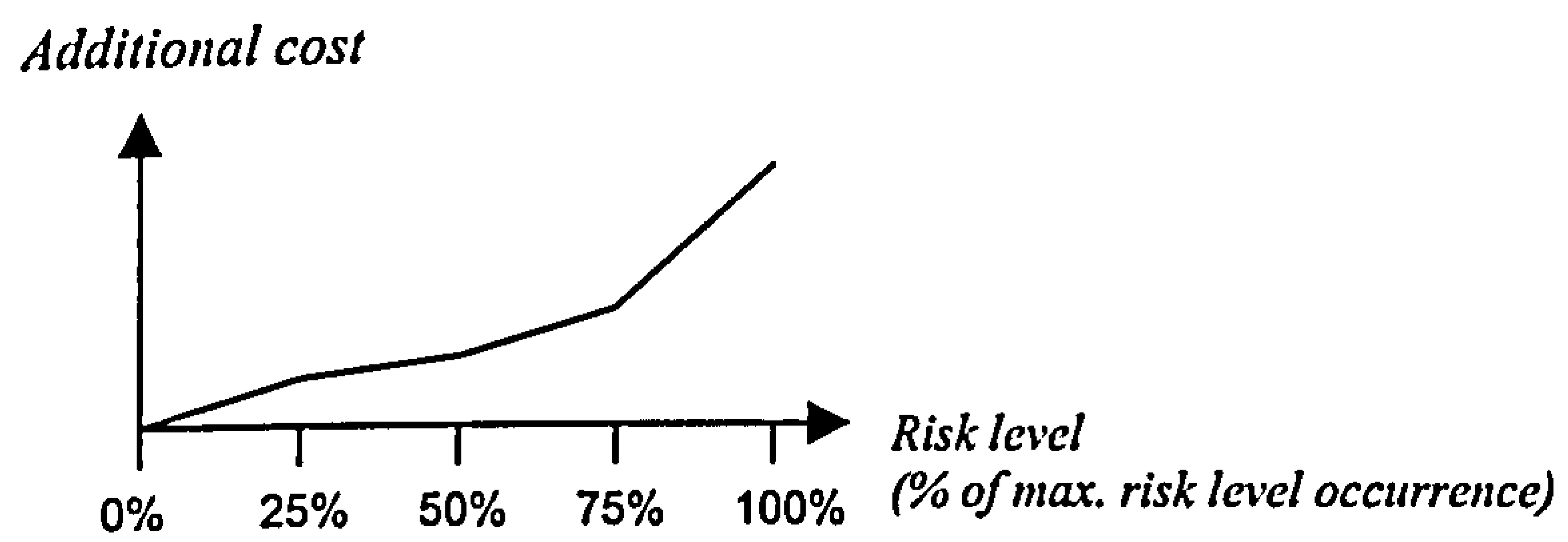


Figure 5.2b

Additional cost-Risk relationship

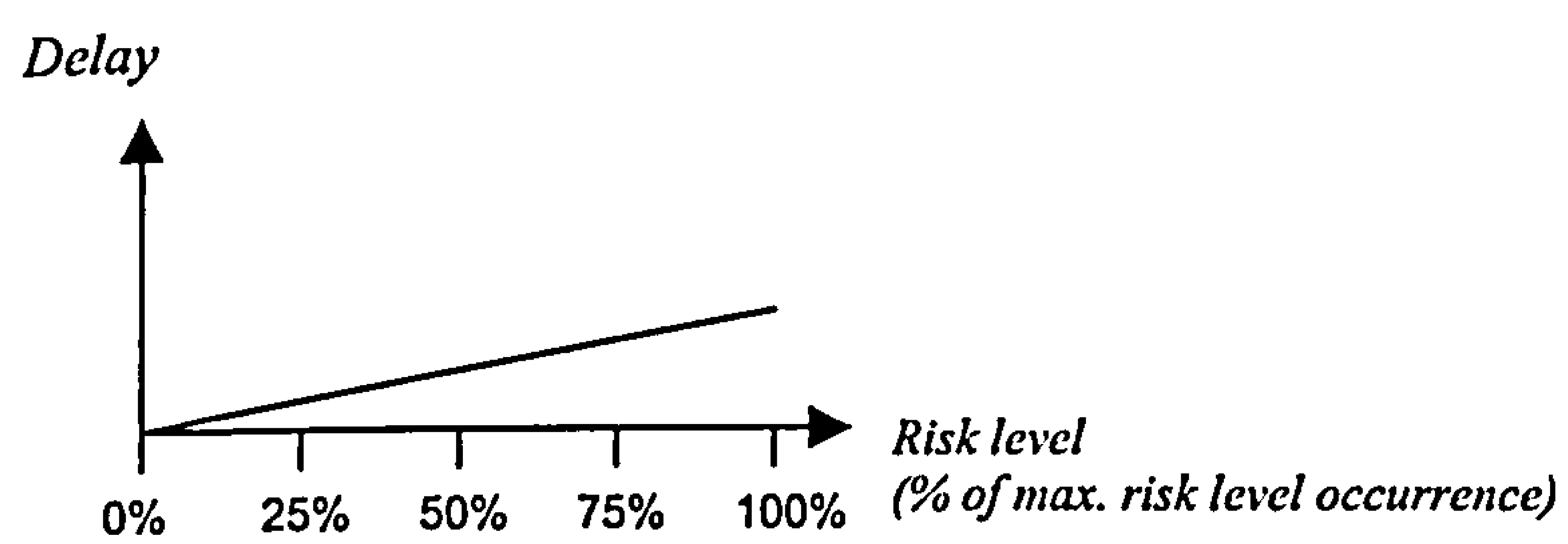


Figure 5.2c

Delay-Risk relationship

In a single simulation, the model generates a random number for each risk. The random number is used to sample a particular risk level from its distribution (Figure 5.2a). The sampled risk level is that which has the cumulative probability equal to the randomly generated number (this is the sampling method commonly associated with Monte Carlo simulation (Vose, 1996)). Subsequently, the simulated additional cost and delay values for the respective risk are taken as those that correspond to the sampled risk level (Figures 5.2a and 5.2b). Linear interpolation between the additional cost and delay values estimated at the quarterly risk levels is used to obtain the simulated additional cost and delay values.

In order to obtain the total simulated cost of an activity in a single simulation, the above process is repeated for each risk related to the activity. The total simulated cost of the activity is equal to the sum of the activity's base cost and each of its risks' simulated additional costs. Meanwhile, the total simulated duration of the activity is equal to the sum of the activity's base duration and the maximum delay value simulated from amongst the activity's risks. It is therefore assumed that the risk events run in parallel, rather than in series, but the cost of the risk events is cumulative.

To summarise, the quantification process of the refined model requires the model-user to make the following estimates for each user-specified activity:

- activity's base cost (i.e. cost assuming negligible risk levels for all of the activity's risks)
- activity's base duration (i.e. duration assuming negligible risk levels for all of the activity's risks)
- (for each risk specified for the activity) additional cost and delay if the risk occurs at 0%, 25%, 50%, 75% and 100% of the maximum risk level occurrence.
- (for each risk specified for the activity) most likely quarterly risk level

<u>An example of how the refined model's quantification process calculates the cost and duration of an activity</u>

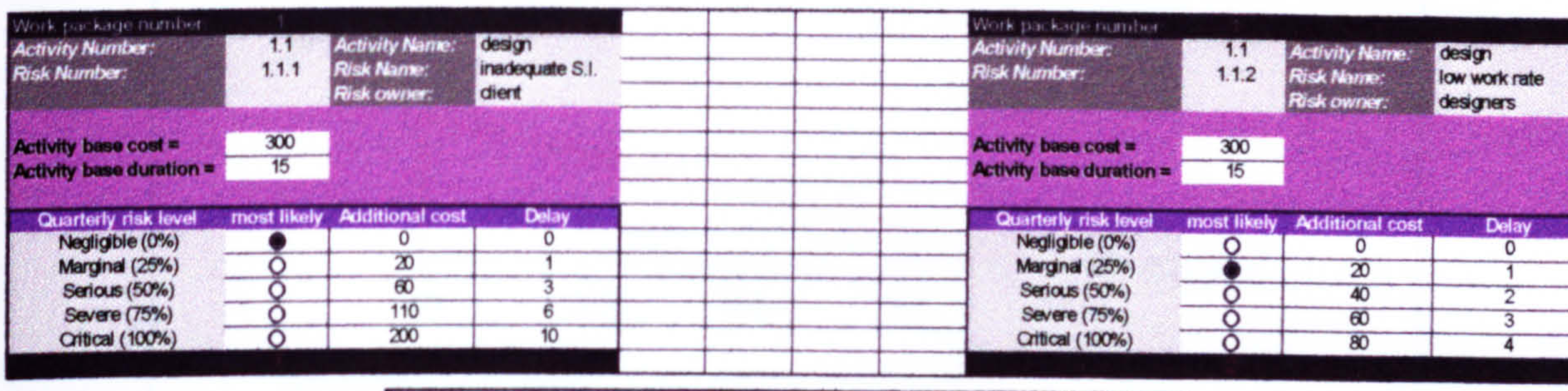
Consider an activity named 'design'.

Rather than analyse the general activity risk, the model-user chose to analyse two specific risks related to the activity:

Risk 1: re-design owing to an inadequate site investigation

Risk 2 : low productivity rate of design team

Figure 5.3 is a screen-shot from the refined model. It presents the model-user's estimates for the example activity.



Work package number 1

Activity Number:	1.1	Activity Name:	design
Risk Number:	1.1.1	Risk Name:	inadequate S.I.
		Risk owner:	client

Activity base cost = 300
Activity base duration = 15

Quarterly risk level	most likely	Additional cost	Delay
Negligible (0%)	●	0	0
Marginal (25%)	○	20	1
Serious (50%)	○	60	3
Severe (75%)	○	110	6
Critical (100%)	○	200	10

Work package number 1

Activity Number:	1.1	Activity Name:	design
Risk Number:	1.1.2	Risk Name:	low work rate
		Risk owner:	designers

Activity base cost = 300
Activity base duration = 15

Quarterly risk level	most likely	Additional cost	Delay
Negligible (0%)	○	0	0
Marginal (25%)	●	20	1
Serious (50%)	○	40	2
Severe (75%)	○	60	3
Critical (100%)	○	80	4

<u>Note:</u> All cost values are in units of £k
All time values are in units of weeks

Figure 5.3 Estimates for the example design activity and its related risks (screen-shot from the refined model)

Figure 5.4 shows a graphical representation of the estimates for Risk 1.

In a single simulation the model performs the following process to obtain the simulated cost and duration of the design activity:

<u>Risk 1</u>

	Random number generated	= 0.84175
hence,	sampled risk level	= 60.2% of max. risk level occurrence (see cumulative probability distribution in Figure 5.4)
	simulated additional cost	= £80.4k (see Figure 5.4)
	simulated delay	= 4.2wk (see Figure 5.4)

<u>Risk 2</u>

	Random number generated	= 0.27109
hence,	sampled risk level	= 26.1% of max. risk level occurrence
	simulated additional cost	= £20.8k
	simulated delay	= 1.0wk

Simulated design activity cost = activity base cost + (additional cost)$_{\text{Risk 1}}$ + (additional cost)$_{\text{Risk 2}}$
= £300k + £80.4k + £20.8k
= £401.2k

Simulated design activity duration = activity base duration + (delay)$_{\text{Risk 1}}$ *[note: (delay)$_{Risk\ 1}$ > (delay)$_{Risk\ 2}$]*
= 15wk + 4.2wk
= 19.2wk

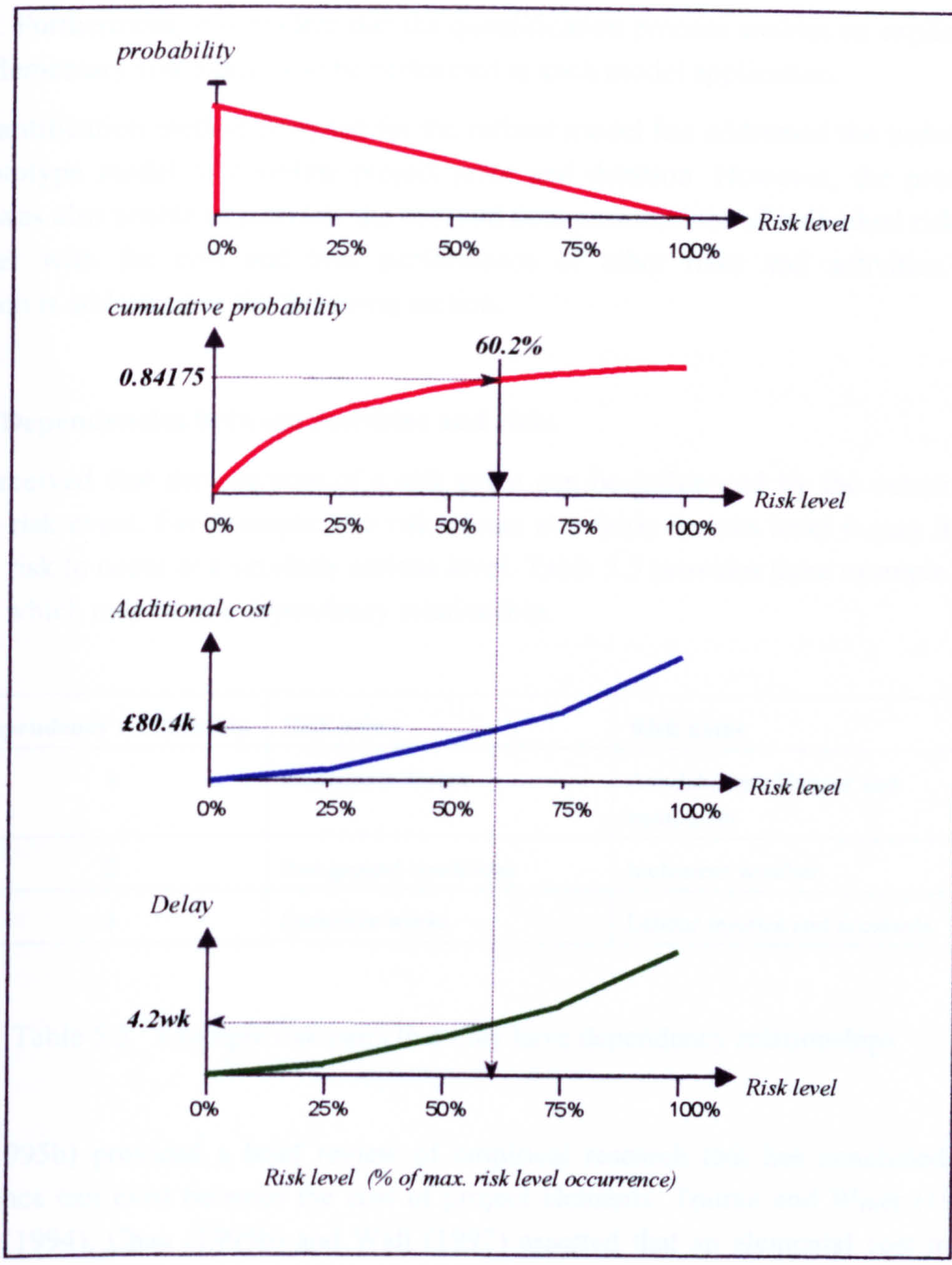


Figure 5.4 Graphical representation of the estimates for Risk 1

The use of quarterly risk levels followed the principles of a simple scenario approach where a few discrete events relating to a risk are analysed. For example, Chapman and Ward (1997) described a method where a risk is quantified for each of three scales of impact; low, medium and high impact. The decision to divide the risk scale, used by the refined model, into five discrete levels and assign a qualitative label to each level was based upon a technique reported by Godfrey (1996).

This section has demonstrated that the refined model's quantification method ensures that the project price is correlated with the project duration in each simulation run of a project. Furthermore, it is evident that the quantification process enables an explicit and fairly elementary risk analysis to be performed in each model application.

The quantification method designed for the refined model has addressed the inability of the prototype model to correlate project price and duration. However, the prototype model was also unable to correlate the cost and time performance of individual risks and activities with the cost and time performance of other risks and activities. This limitation is addressed in the following section.

5.1.3 Dependencies between activities and risks

It is perceived that the outcome of a risk event can be influenced by the outcome of another risk event. For example, if a risk occurs at a fairly serious level it may induce another risk to occur at a similarly serious level. Table 5.3 provides three example pairs of risks which may have a dependency relationship.

Dependency relationship	Risk name	Risk name
1	Inadequate design	Availability of labour and equipment
2	Bad ground conditions	Inclement weather
3	Defective works	Labour injuries and accidents

Table 5.3 Example risk pairs that may have dependency relationships

Chau (1995b) provided a brief review of empirical research that has concluded that dependence can exist between the cost of project elements. Touran and Wiser (1992), Raftery (1994), Chau (1995b) and Wall (1997) asserted that an elemental cost model that applies Monte Carlo simulation must model any significant dependencies that exist between variables. However, in risk analysis literature there are very few fully-documented techniques that can model dependencies between variables.

Cooper and Chapman (1987) reported that dependencies could be modelled using conditional probabilities. However, even they conceded that this method requires a considerable amount of computation and specification effort.

Cooper and Chapman (1987) reported a method that may be used to bench-mark and check estimated conditional probabilities. The result of the method is a single percentage value intended to give an approximate measure of the dependency between two variables. Cooper and Chapman insisted that percentage dependence is not suitable for specification purposes. However, owing to the considerable reduction in specification effort that this method offered, relative to the use of conditional probabilities, it was decided to investigate whether the method could model dependencies.

Since Cooper and Chapman applied the method to variables represented by histogram probability distributions, it was necessary to adjust the technique so that it may be applied to variables represented by triangular probability distributions (i.e. risks that may assume a continuous range of risk levels – see Figure 5.2a). The resultant technique is described in Figure 5.5 under the heading of Technique 1.

Technique 1 inspired the development of similar techniques that relied upon the specification of a single dependence value. The techniques were variations upon fairly basic mathematical manipulations. Each technique equated to a slightly different interpretation of the single value specified to represent a dependency relationship. Technique 2 described in Figure 5.5 is an example derivative of Technique 1.

The following techniques aim to model a dependency relationship between two risks (R1 and R2). Each risk's level of occurrence is represented by a probability distribution. The degree of dependence between the risks is to be specified as a single percentage value. Assume 80% dependence (i.e. 20% independence) has been specified for R1 and R2.

Technique 1

A random number (N1) is generated. The level of R1 is taken as that which has a cumulative probability value equal to the random number. Using the same random number and method, the corresponding level of R2 is derived (see Figure (i)). This level of R2 represents the level where R2 is 100% correlated with R1 (i.e. R2(100%)).

A second random number (N2) is generated. A second level of R2 is taken as that which has a cumulative probability value equal to the random number(see Figure (i)). This level of R2 represents the level where R2 is 0% correlated (i.e. independent) with R1 (i.e. R2(0%)).

The two levels of R2 are then combined to give a single level that reflects 80% dependence. The two levels of R2 are weighted in accordance with the specified percentage dependency level using the following equation:

$$[0.8 \times R2(100\%)] + [0.2 \times R2(0\%)]$$

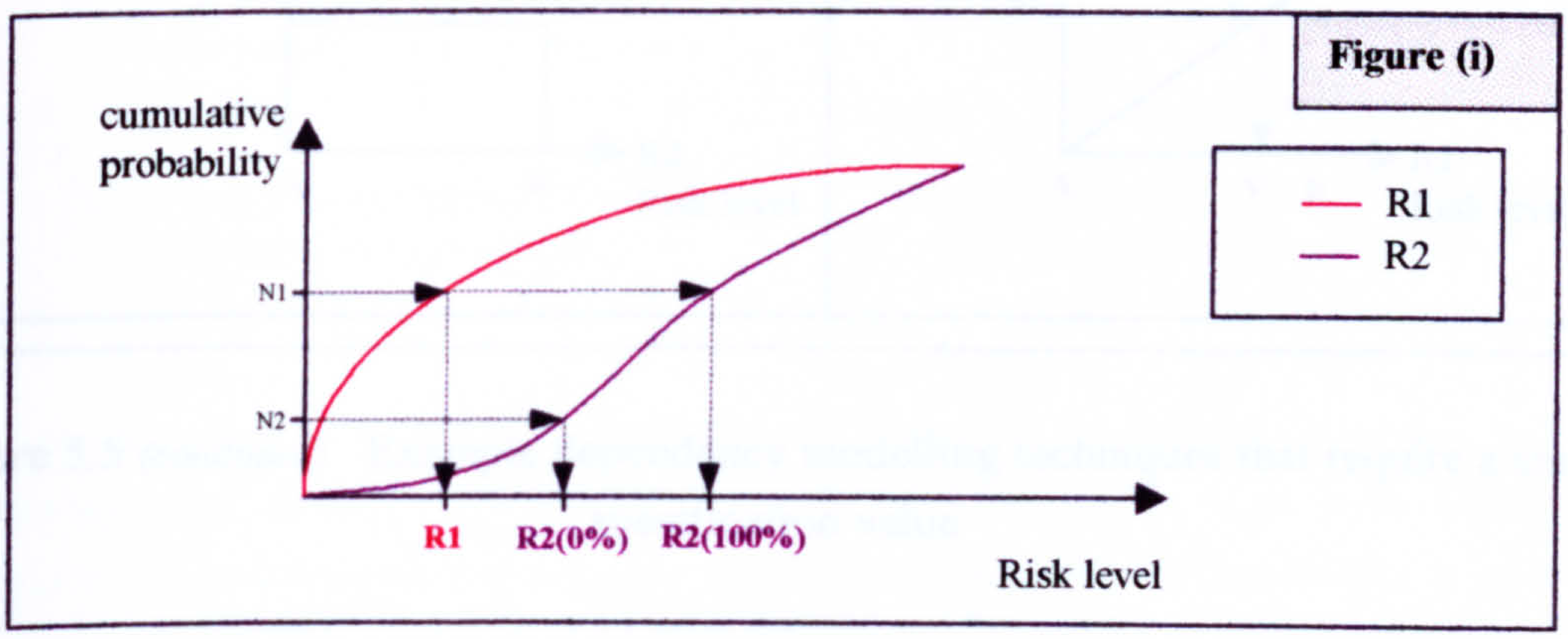


Figure 5.5 Example dependency modelling techniques that require a single specification value *(continued overleaf)*

Technique 2

A random number (N1) is generated. The level of R1 is taken as that which has a cumulative probability value equal to the random number. Figure (ii) shows that N1 dictates that the level of R1 is equal to X in this simulation.

The level of R2 is then restricted to a new range of values. The minimum value of this range equates to the value of R2 which has a cumulative probability value equal to the initially generated random number minus 0.1 (0.1 corresponds to half of the 20% independence specification). Similarly the maximum value of the range equates to the value of R2 which has a cumulative probability value equal to the initially generated random number plus 0.1. If the cumulative probability values calculated in the previous step lies outside the limits of zero or one, the relevant limiting value is used.

Figure (ii) shows that the level of R2 is now restricted to the range between A and B for this simulation. It is assumed that R2 has an equal probability of assuming any value within the new range (i.e. R2 is now represented by a uniform distribution, irrespective of R2's original distribution – see Figure (iii)). A second random number (N2) is generated. The level of R2 is taken as the level within the uniform distribution which has a cumulative probability value equal to the random number (see Figure (iv)). Figure (iv) shows that N2 dictates that the level of R2 is equal to Y in this simulation.

The simulated levels of R1 and R2 are X and Y, respectively. It is intended that the values X and Y exhibit the specified 80% dependency between R1 and R2.

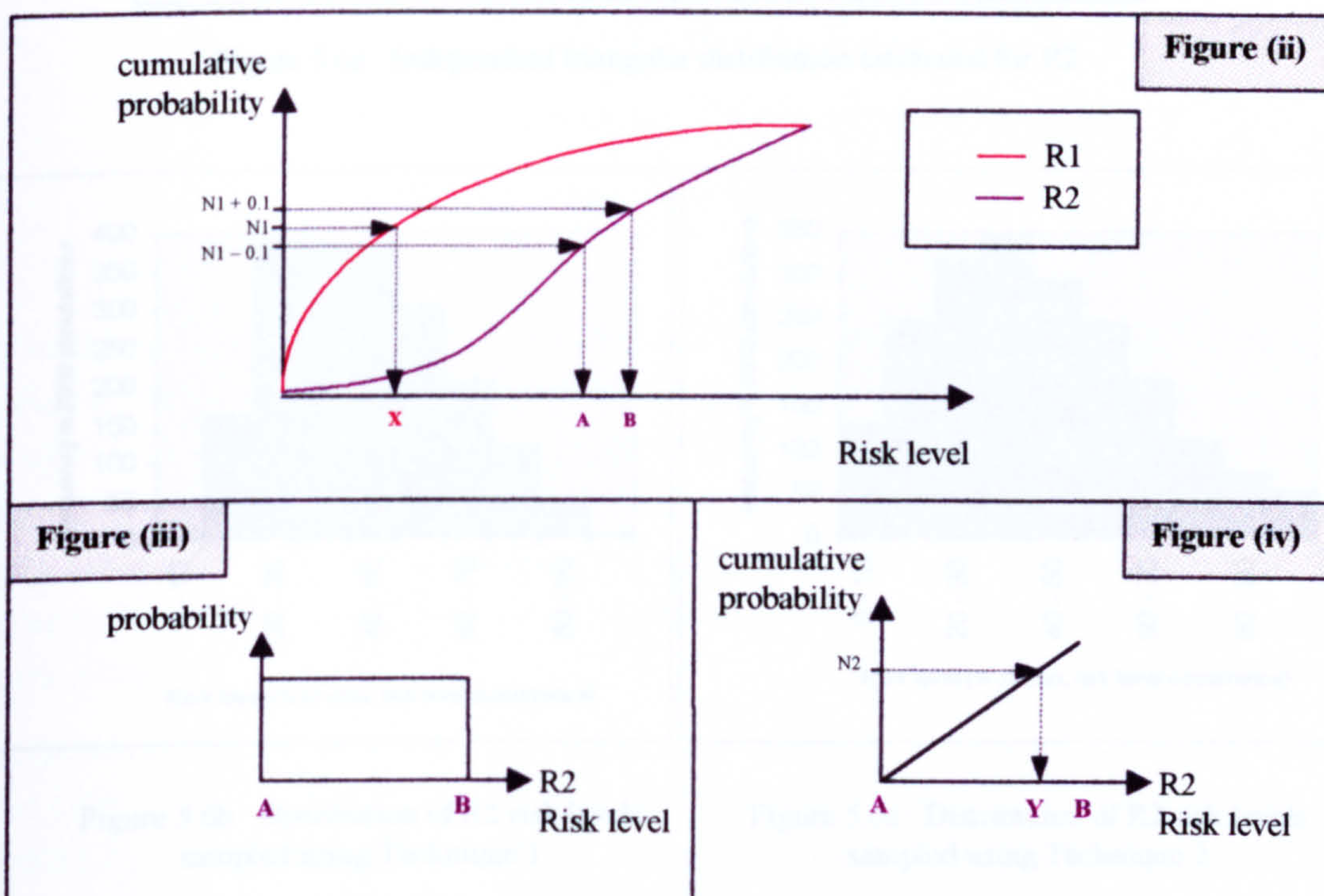


Figure 5.5 *(continued)* Example dependency modelling techniques that require a single specification value

Tests were conducted on these proposed dependency modelling techniques. Each dependency technique was used to sample values from two variables' independent probability distributions. The sampling process was repeated 2000 times. Each variable's 2000 sampled values were then arranged into a probability distribution (i.e. histogram). The test results showed that all of the techniques, including the two described in Figure 5.5, introduced some biases into the sampling process. The presence of biases in the sampling process was evident from the difference in shape between the dependent variable's originally estimated independent distribution and its sampled distribution. Figures 5.6a, 5.6b and 5.6c contrast the distributions of risk levels for R2 sampled using Techniques 1 and 2 (described in Figure 5.5) with the original distribution estimated for R2.

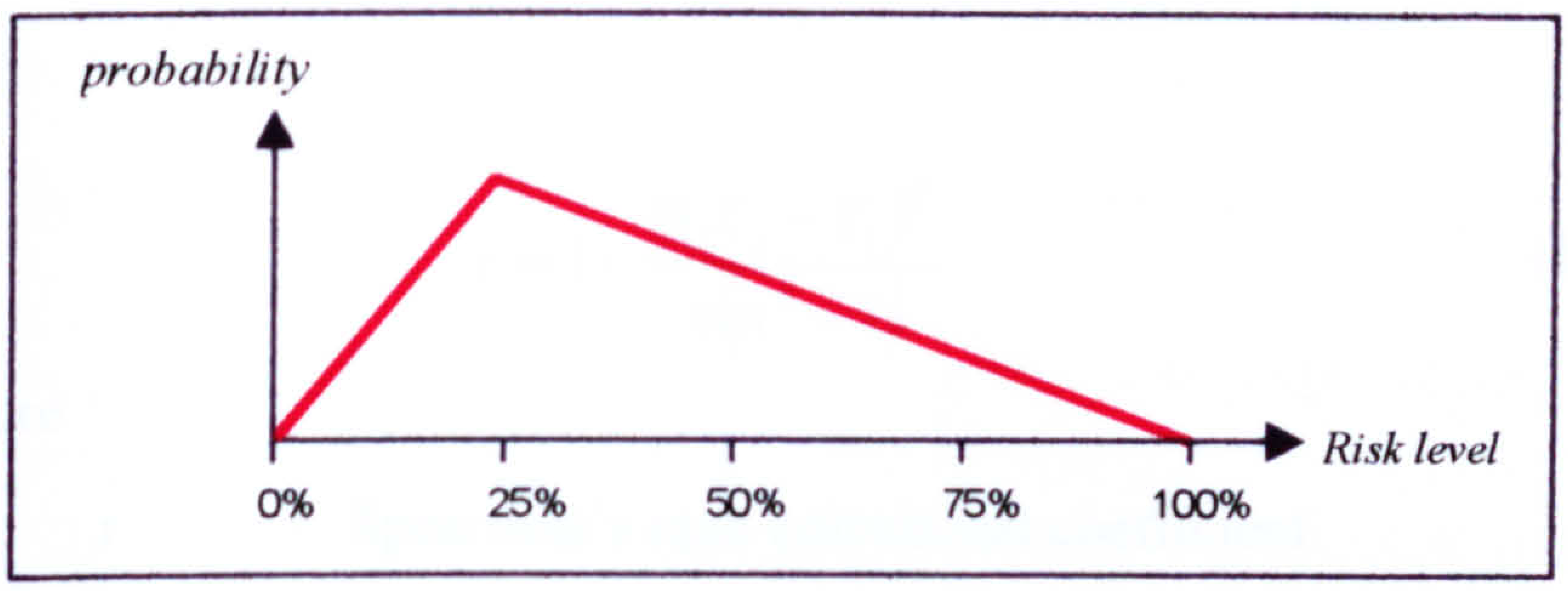


Figure 5.6a Independent triangular distribution estimated for R2

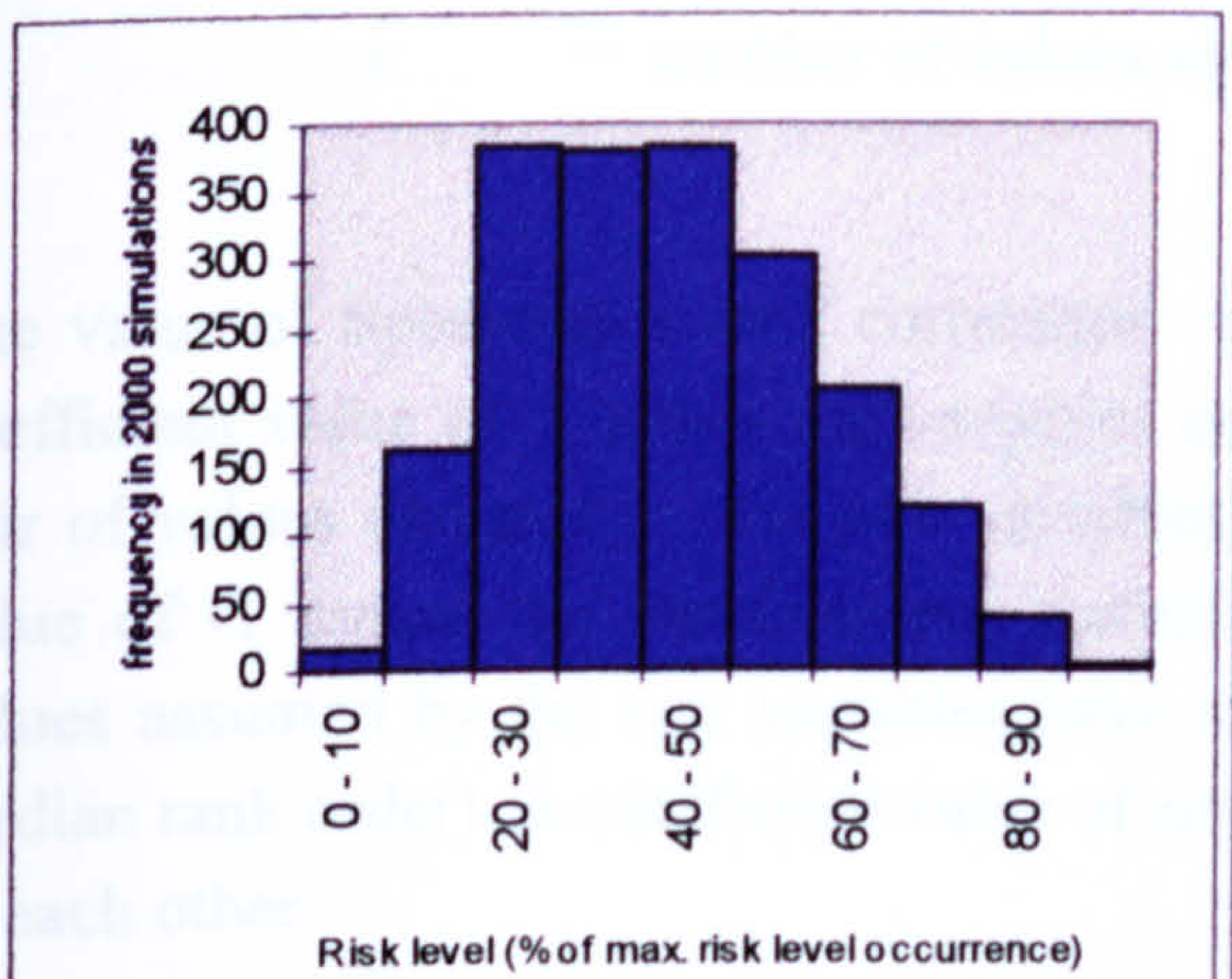


Figure 5.6b Distribution of R2 risk levels sampled using Technique 1

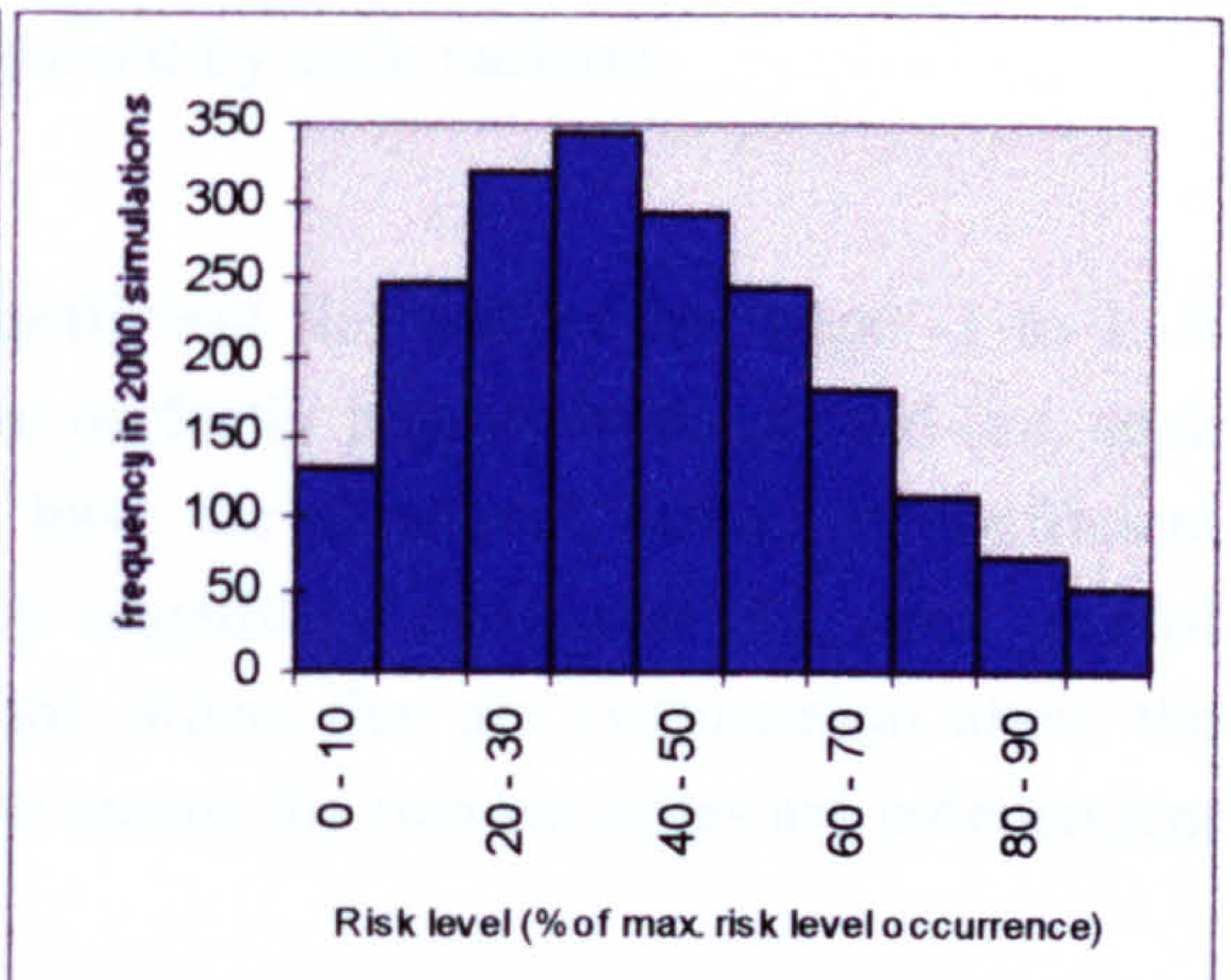


Figure 5.6c Distribution of R2 risk levels sampled using Technique 2

Following a review of commercial risk analysis software it was discovered that Palisade Corporation had developed software that utilised Spearman's rank order correlation coefficient to model dependencies. The dependency between two variables is specified as a single value. The technique was described as 'distribution-free' because any types of distributions may be correlated and the technique did not bias the sampling process

(Palisade Corporation, 1996). Furthermore, the technique can model a scenario where a variable is dependent upon more than one other variable (Palisade Corporation, 1996).

The actual mechanics of the technique based upon Spearman's rank order correlation coefficient are not widely disclosed, but may be found in Iman and Conover (1982). Owing to the length and complexity of the technique, a description of its mathematical process is not provided.

Correlation techniques measure the degree of linear relationship between two variables (Caswell, 1989). Spearman's rank correlation coefficient (r) is a measure of correlation between the order in which each variable's values are ranked as opposed to the variable's actual values. The value of the coefficient is calculated using the following formula:

$$r = 1 - \frac{6(X_i - Y_i)^2}{n(n^2 - 1)} \qquad \text{(Equation 5.1)}$$

where

r	=	Spearman's rank correlation coefficient
X_i	=	the rank order of the i^{th} value assumed by variable X
Y_i	=	the rank order of the i^{th} value assumed by variable Y
n	=	number of values assumed by each variable

The value of Spearman's rank correlation coefficient lies within the range -1 to 1. A coefficient value of 1 means the variables are perfectly positively correlated (i.e. each pair of values assumed by the two variables have the same rank order). A coefficient value of -1 means the variables are perfectly negatively correlated (i.e. each pair of values assumed by the two variables have rank orders that are symmetrical about the median rank order). A coefficient value of zero means the two variables are independent of each other.

In order to model the dependency between two variables, a value of Spearman's rank order correlation coefficient has to be specified. Assistance to the estimator may be provided by a graphical presentation of the relationship for specific coefficient values. Figures 5.7a and 5.7b are scatter plots that indicate the general trend of paired values of variables X and Y for two different coefficient values. The Spearman's rank order correlation coefficient value that gives the sampled values of X and Y in Figures 5.7a and 5.7b are 0.2 and 0.9, respectively.

The refined model incorporates the dependency modelling technique based upon the Spearman's rank correlation coefficient. The model-user is required to specify the coefficient value between any risks considered to be correlated.

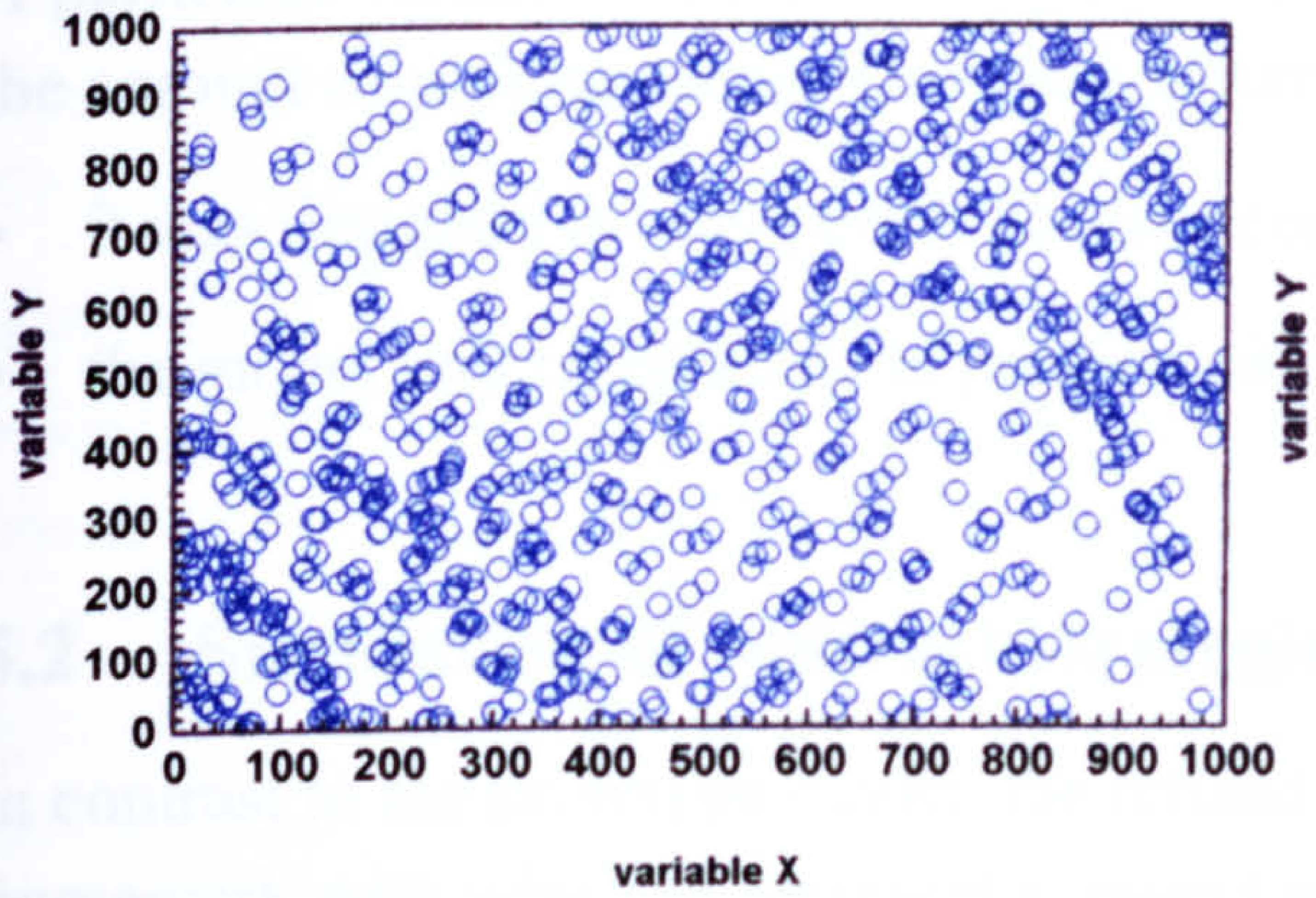


Figure 5.7a
A scatter plot of paired values of variables X and Y that have a Spearman's rank correlation coefficient equal to 0.2

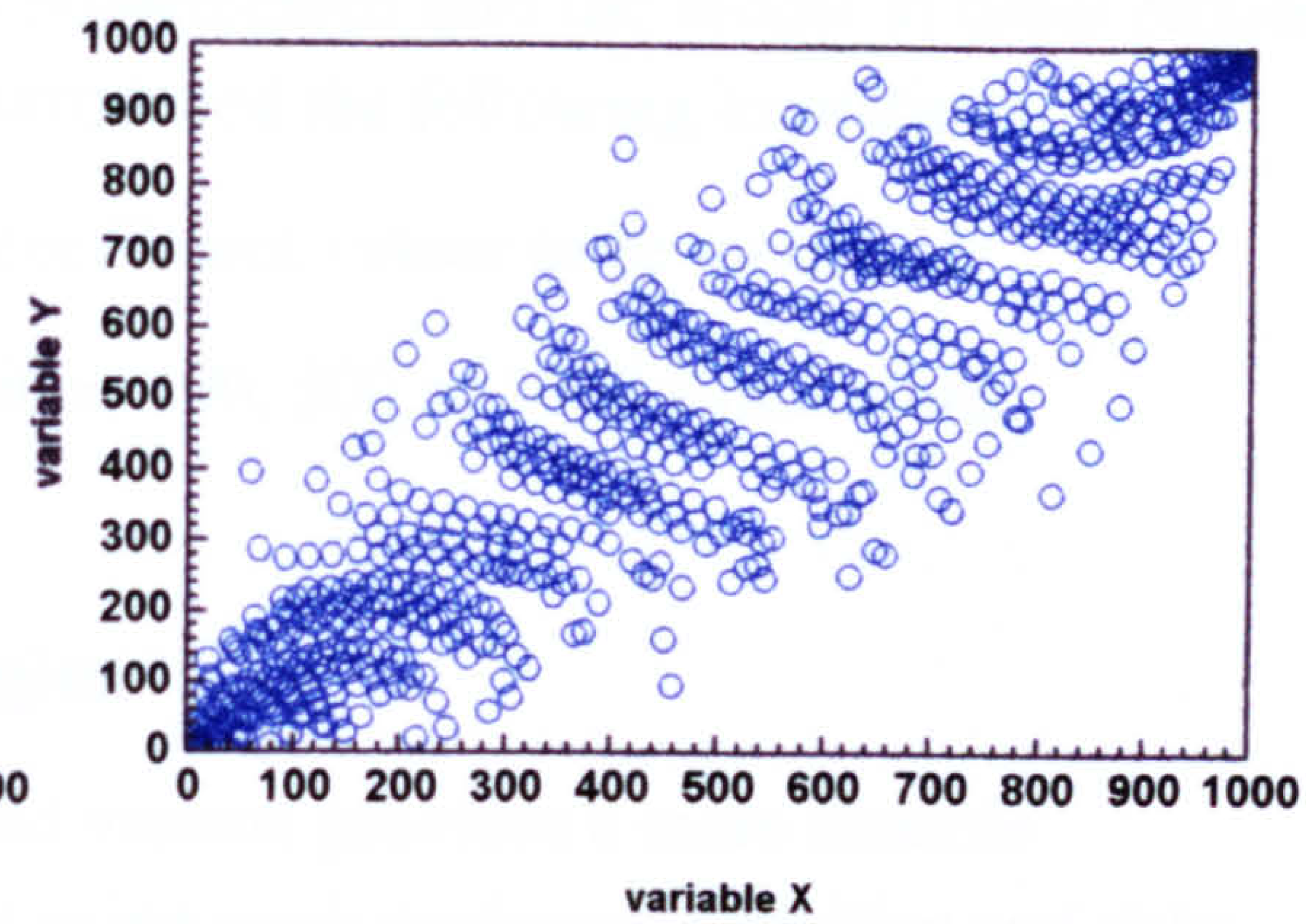


Figure 5.7b
A scatter plot of paired values of variables X and Y that have a Spearman's rank correlation coefficient equal to 0.9

The model presents an empty matrix where all of the user-specified risks are listed as both its row and column headings. In order to specify a dependency relationship between a pair of risks the user has to insert the appropriate coefficient value into the corresponding matrix position. Figure 5.8 shows an example matrix. In this example, the dependency between Risk 1 and Risk 2 is reflected in the coefficient estimate 0.3. The dependency between Risk 2 and Risk 3 is reflected in the coefficient estimate of 0.5. Meanwhile Risk 1 and Risk 3 are assumed to be independent.

	Risk 1	*Risk 2*	*Risk 3*
Risk 1	1	0.3	0
Risk 2	0.3	1	0.5
Risk 3	0	0.5	1

Figure 5.8 An example matrix of Spearman's rank correlation coefficients that denote the degree of dependency between the three risks

It should be noted that the dependency modelling technique based upon Spearman's rank correlation coefficient imposes certain limitations. These include:

- the technique presumes that the correlation between two variables is linear;
- the technique presumes that both variables are dependent on the other, as opposed to one variable being dependent upon an independent variable.

A particular variation of the technique was implemented into the model in order reduce the amount of programming. This version introduced the following limitations:

- it was designed to only permit positive coefficient values to be modelled;
- the model was constrained to perform either 100, 500 or 1000 simulations.

5.2 Simulation of contract strategies

In contrast to the prototype model, the refined version provides a more flexible framework with which to represent a project using work packages, activities and risks. As a result, it is possible to provide a more sophisticated representation of each contract strategy under consideration. The following sub-sections report that the model facilitates simulation of contract strategies' assignment of work and risk, pricing mechanisms, tender processes, consultant fees and timing of the client's payments to each contracted party.

5.2.1 Organisational structure

Three contract strategies were modelled in the prototype model. In each definition of these three contract strategies reference was made to one of the following general organisational structure labels:

- Traditional
- Design-Build
- Management Contract

It is appreciated that these organisational structure labels are not definitive. There are many variations of organisational structures which may be referred to using each of these labels. In other words each label is open to considerable interpretation, but there is a common understanding as to the general type of organisational structure associated with each of these labels. Table 2.1 in section 2.1.1 defined each of the above listed organisational structure types as follows:

- Traditional: design completed by consultants before construction is awarded to a contractor
- Design-Build: both detailed design and construction performed by a contractor
- Management Contract: design by consultants; management contractor appointed early and work packages let progressively by the management contractor.

It is apparent that these widely accepted definitions of organisational structure types primarily define the division of design, construction and management responsibilities. The three contract strategies featured in the prototype model were modelled in such a way that they allocated design, construction and, in one case, management responsibilities in a specific configuration. The configuration imposed by each of the three contract strategies is reported in Table 5.4.

Each of the three contract strategies either dictated that total design was an independent work package (Traditional and Management Contract) or grouped total design and construction together as a single work package (Design-Build). Therefore it was possible to construct the prototype model so that, in any application, the design activity was always a complete activity. Table 5.4 also indicates that the prototype model was designed to group construction as a single work package that is allocated to a single contractor. Again, this compromise was justified because the model was designed only to simulate the three previously-cited contract strategies.

Organisational structure type	Division of project work
Traditional	• Entire design allocated to one party • Entire construction allocated to one party
Design-Build	• Entire design and construction allocated to one party
Management Contract	• Total design allocated to one party • Management services provided by one party • Construction work completed by several works contractors (the prototype model treated the works contractors as a single party)

Table 5.4 Division of project work dictated by the three contract strategies featured in the prototype model

In order for the refined model to simulate a wider variety of contract strategies it was necessary to increase the flexibility with which a contract strategy's division of work could be modelled and subsequently evaluated. Therefore a framework was designed that enabled a contract strategy's division of work to be modelled in terms of the appropriate number of work packages.

Since the model is intended, primarily, to be used by the client organisation, the work packages should equate to the prime contracts held by the client with contracting parties. Therefore, in the case of the Traditional contract strategy featured in the prototype model, two work packages could be modelled. One work package would represent the client's contract with the designer while the other work package represented the client's contract with the general contractor.

It is possible to model subcontracts in addition to prime contracts. However, a modelled prime contract must not incorporate the details of a subcontract if the subcontract is to be modelled separately. The Management Contract featured in the prototype model could be modelled as:

- one work package for the design work;
- one work package for just the management services provided by the management contractor; and
- as many work packages as number of works contractors appointed under the management contractor.

In order to distinguish which aspects of work are assigned by a contract strategy to different contracting parties, the refined model prompts the user to specify names for each party assigned responsibility for a work package. It should be noted that the model is programmed to recognise the name "client" as a reference to the client organisation. Meanwhile, the user can specify any name for the contracting parties, although the names must be consistent throughout an application of the model. Section 5.2.2 reports that the parties' names are used to define a contract strategy's risk allocation.

For each specified work package the model-user has the option to analyse the affect of a:

- pricing mechanism (see section 5.2.3);
- tender process (see section 5.2.4); and
- management/consultant's fee (see section 5.2.5).

Figure 5.9 displays a screen-shot where a contract strategy's work packages have been specified. In this example the first work package is to be undertaken by the client whilst the second is to be undertaken by a party named by the model-user as "Contractor". The model-user has opted to evaluate the affect of a type of pricing mechanism, tender process and consultant's fee on the second work package. A party named "Manager" is to receive the consultant's fee.

Work package number	Contracting party label	Tender process	Pricing mechanism	Mngmt/Consultnts fee	
1	client	☐	☐	☐	
2	Contractor	☑	☑	☑	Manager

Figure 5.9 An example set of inputs that defines the division of work and which work packages the user has opted to analyse the effect of a pricing mechanism, tender process and management/consultant fee

It has been acknowledged that the framework designed to define a contract strategy's division of work permits prime contracts and subcontracts to be modelled. It is also possible to model a contract in which different aspects of work, within that contract, are to be paid using different pricing mechanism types. This can be achieved by separating the different aspects of work that are to be paid using different pricing mechanism types into individual work packages, whilst accrediting each work package to the same contracting party.

In contrast to the prototype model, the refined version provides a more flexible framework to simulate the organisational structure of contract strategies. However, it does not provide a comprehensive representation. As with the prototype model, an application of the refined model requires the user to interpret and reflect the specific details about each contract strategy's organisational structure in his/her cost and time estimates that are inputted into the model.

Although the refined model is not programmed to recognise descriptive labels such as Traditional and Design-Build, the model prompts the user to specify any label for the organisational structure associated with each contract strategy evaluated. This is purely a reference label.

5.2.2 Risk allocation

The preceding section reported that a contract strategy's division of work is simulated by defining a series of work packages. This process is the first step in an application of the refined model. The next step is to divide each work package into a series of activities and risks.

Section 5.1.1 reported that the refined model enabled the user to specify any number and type of activities. It also reported that the model-user has the option to either specify and analyse the general risk associated with each activity or specify and analyse more than one specific risk related to each activity.

The refined model was designed to simulate the particular risk allocation of each evaluated contract strategy. Each identified and quantified risk is to be allocated to a party. The risk owner names must be consistent with the party names assigned when the contract strategy's division of work was specified.

During the empirical research the industrialists who completed questionnaires indicated that they interpreted a contract strategy's general division of risk between the client and main contractor from the contract strategy's general organisational structure label and, to a lesser extent, from the pricing mechanism type. The design of the refined model aims to make the particular risk allocation of each evaluated contract strategy explicit and thus aid contract strategy selection and risk management.

5.2.3 Pricing mechanism

The prototype model simulated a single pricing mechanism type for each of the three contract strategy options (see section 3.3.2.2). For each option the model simulated the pricing mechanism implemented within the contract between the client and the contractor that is assigned responsibility for the construction (i.e. the principal contractor). Table 5.5 displays the common reference label of the principal contractor and pricing mechanism type that governed the principal contractor's reimbursement within each of the three contract strategies.

Contract strategy	**Common title of principal contractor**	**Pricing mechanism type**
Traditional	General contractor	Guaranteed maximum price
Design-Build	Design-Build contractor	Fixed lump sum
Management Contract	Works contractors	Cost plus percentage fee

Table 5.5 The principal contractor and pricing mechanism types associated with each of the three contract strategies featured in the prototype model

In contrast, the refined model permits the user to analyse the effect of a pricing mechanism type for each specified work package within a given contract strategy. Therefore it is possible to simulate a contract strategy where the client lets a series of contracts, amongst which different pricing mechanism types are implemented. In addition, section 5.2.1 acknowledged that the model could be used to model a single contract in which different aspects of work within that contract are to be paid for using different pricing mechanism types, providing each is specified as an individual work package.

The main purpose of modelling pricing mechanisms is to conduct a more rigorous calculation of the client's price for particular work packages and to assess the possible effect that a pricing mechanism type may have on the price. However, since modelling pricing mechanisms requires the user to distinguish between the contractor's costs and the contractor's tender bid, it is possible to calculate the contractor's financial outcome in addition to the client's price for the work package.

The prototype model did not perform this calculation. It is perceived to be a very valuable addition to the model because it assists the user to assess whether the estimated tender bids are realistic. It can also provide insights into whether a contract strategy's risk allocation is equitable as well as efficient from the client's perspective. It is in the client's interests to give the contractor sufficient incentive to execute and complete work to the required standards and also to avoid insolvency of the contractor.

The refined model imposes a restriction on the pricing mechanism types that can be simulated. Nonetheless, the range of options are considered the most common. The options include:

- lump sum;
- target cost (with Guaranteed Maximum Price);
- target cost;
- cost plus fixed fee; and
- cost plus percentage fee.

The first, second and fifth options in the above list are the same pricing mechanism types as those incorporated in the three contract strategy options featured in the prototype model. Table 5.6 reports the tender bid parameters and mathematical formulae used to calculate the client's price for a work package as well as the contractor's financial outcome if any of the above-listed pricing mechanism types are specified for a work package.

5.2.4 Tender process

The three contract strategy options within the prototype model included reference to a tender process type used to appoint the principal contractor (and management contractor for the Management Contract option). In contrast, the refined model gives the user the option to account for the tender process associated with each specified work package.

For each tender process chosen to be modelled, the user is prompted to specify whether the tender process includes one or two stages. The user's response governs whether the relevant work package contains one or two tender activities. The user is also prompted to assign a reference label to each modelled tender process.

Pricing mechanism type	Tender bid parameters	Client's price (P) for work package	Work package contractor's financial outcome (R)
Fixed price	Fixed price (V)	$P = V$	$R = V - (B^* + Y^*)$
Target cost (with Guaranteed Maximum Price)	• Guaranteed maximum price (G) • Target contract cost (T) • Target fee (fixed) (F) • Sharing rate (b)	If $C + F + b(T - C) < G$ [where $C = (B^* + X^*)$] Then $P = C + F + b(T - C) + Y^*$ Else $P = G + Y^*$	If $C + F + b(T - C) < G$ [where $C = (B^* + X^*)$] Then $R = F + b(T - C)$ Else $R = G - C$
Target cost	• Target contract cost (T) • Target fee (fixed) (F) • Sharing rate (b)	$P = C + F + b(T - C) + Y^*$ [where $C = (B^* + X^*)$]	$R = F + b(T - C)$ [where $C = (B^* + X^*)$]
Cost plus fixed fee	Fixed fee (F)	$P = B^* + Y^* + F$	$R = F - X^*$
Cost plus percentage fee	Percentage fee level (f)	$P = B^*(1 + f) + Y^*$	$R = fB^* - X^*$

Notes:

B^* = sum of each activity's base cost within the work package

X^* = sum of the contractor's risk costs within the work package

Y^* = sum of the client's risk costs within the work package

If the Target cost type pricing mechanism is used with the intention to share the cost of risks between the client and contractor, the user must specify the contractor as the owner of each relevant risk

The sharing rate (b) is treated as a deterministic variable because it is assumed that its value is dictated by the client. In the context of the above formulae, the sharing rate is interpreted to mean the proportion of savings/losses of the actual work package cost, relative to the target cost, that the client pays/receives to/from the work package contractor.

Table 5.6 Pricing mechanism types that may be simulated by the refined model, their tender bid parameters and calculation formulae

5.2.5 Management/Consultant fee

Section 5.2.1 reported that for each specified work package the model-user can opt to take account of a management/consultant's fee. This modelling option may be considered applicable where a party is appointed to provide a service that does not involve execution of a particular project production activity. For example, it may be used to model the fee paid to a party that provides purely construction management services.

If the model-user opts to take account of a management/consultant's fee for a particular work package the user is prompted to specify the mechanism used to calculate the fee amount. The refined model permits the fee to be modelled using one of the following options:

- lump sum;
- percentage of work package costs (costs to the client); and
- target fee.

Table 5.7 presents the parameter(s) and the fee calculation formula for each of the above options. Each of the parameters listed in Table 5.7 are to be estimated as triangular probability distributions. This is with the exception of the sharing rate (see Table 5.7 notes).

Management/Consultant Fee type	**Parameters**	**Fee Formula**
Lump sum fee	lump sum (U)	Fee = U
Percentage fee	percentage fee level (g)	Fee = g(B* + Y*)
Target cost fee	• percentage fee (h) • target cost (T) • sharing rate (r)	Fee = h(B* + Y*) + r(T – (B* + Y*))

Notes:

B* = sum of each activity's base cost within the work package

Y* = sum of the client's risk costs within the work package

The sharing rate (r) is treated as a deterministic variable because it is assumed that this value is dictated by the client. In the context of the above formulae, the sharing rate is interpreted to mean the proportion of savings/losses of the client's actual price of the work package, relative to the target cost, that the client pays/receives to/from the consultant.

Table 5.7 Management/consultant fee types that may be simulated by the refined model, their parameters and calculation formulae

5.2.6 Timing of client's payments

The value of money varies with time (Briscoe, 1988; Pilcher, 1992; Parkin *et al.*, 1997; for example). Therefore the real value of money expended by a client is dependent upon the times at which a client pays the contracting parties as well as the overall time period during which a client's monies are expended. Given that construction projects generally cover a considerable time period, cash flow analysis is a useful application. However, in addition, it appeared wholly appropriate to incorporate cash flow analysis as a feature of the contract strategy selection-aid model because:

- the timing of a client's payments is a contract-related decision;
- the model is designed to simulate a project duration that reflects the expected impact of each prospective contract strategy for a given project; and
- cash flow analysis is an elementary add-on to the model because the other model analysis involves calculation of a project's cost and time performance.

As with the prototype model, the output of the refined model includes a distribution of simulated price and duration values that reflect a contract strategy's appropriateness for the project under consideration. The refined model also provides an option to simulate a client's interim payments and thereby use the previously-simulated cost and time values to calculate a distribution of net present values of project price and project revenue.

The net present value calculation of a project's revenue requires the user to input a single estimate of the client's net income from the project once it is in operation along with a single estimate of the number of years over which this income is to be received. It should be noted that the model's net present value calculation assumes that the client receives the annual net income at the beginning of each operational year. In each simulation, the project duration value is taken as the timing of the client's first receipt of net income.

In order to calculate the net present value of a project's price it is necessary to establish a time schedule of the client's payments throughout the project. Therefore the user is prompted to specify the timing of the client's payments for each work package within the contract strategy under evaluation. The model is designed to allow the client's interim payments for each work package to regularly occur either:

- after a specified time interval; or
- at the completion of each activity.

The model-user also has the option to specify an amount for each work package which equates to a lump sum amount paid to the contracting party at the outset of the work package. The model-user is required to estimate a single value for the discount rate.

The refined model is designed to perform a cash flow analysis for each simulated run of the project. The method used to calculate the client's payments at each payment stage is dependent upon which of the two previously-cited interim payment systems is selected for a work package.

If the interim payments for a work package are to take place after a specified time interval, the client's payments at each payment stage are calculated using the following method:

- the price of the work package per unit time is calculated using the following equation:

$$\text{work package price rate} = \frac{(P - L)}{D} \qquad \text{(Equation 5.2)}$$

where,

P = price of work package

L = up-front lump sum

D = duration of work package

- at each payment stage for a work package, the model calculates, from the simulated project schedule, the length of time that the work package was in progress since the preceding payment stage
- at each work package's payment stage, the calculated 'in-progress' time is multiplied by the work package's price rate to give the client's payment at the corresponding payment stage
- the first payment stage of a work package must add any up-front lump sum amount to the client's payment.

Alternatively, if the interim payments for a work package are to take place at the completion of each activity within the work package, the client's payments at each payment stage are calculated using the following method:

- the work package's mark-up per unit time is calculated using the following equation:

$$\text{work package mark-up rate, } m = \frac{P - (B^* + Y^*)}{D} \qquad \text{(Equation 5.3)}$$

where,

P = price of work package

B* = sum of each activity's base cost within the work package

Y* = sum of the client's risk costs within the work package

D = duration of work package

- the cost of each activity, which equates to the client's payment at each payment stage, is calculated using the following equation:

$$\text{activity cost to client} = B + Y^* + md \qquad \text{(Equation 5.4)}$$

where,

B = base cost of the activity

Y^* = sum of the client's risk costs within the work package

m = work package mark-up rate

d = simulated duration of the activity
(i.e. includes the activity's base duration and its maximum risk delay)

- the first payment stage of a work package must add any up-front lump sum amount to the client's payment.

Once the model has calculated the client's payment at all of the payment stages for all of the work packages, the model calculates the net present value of the project price for each simulated run of the project. It was previously reported that, in each simulation, the project duration value is taken as the timing of the client's first receipt of net income. The model subsequently calculates the net present value of the project revenue. This value is added to the net present value of project price calculated for the corresponding simulation run to give a net present value of the project.

5.3 A summary of model inputs

Figure 5.10 shows the seven steps which the user must follow to obtain a complete set of inputs for a single contract strategy (Step 7 is optional). Demonstrations of these model input steps are provided by the applications of the refined model to two example projects in Chapter 6.

Figure 5.10 indicates that an application of the refined model presents a demanding task. Although a fairly crude definition of a project might only require, say, ten activities, the minimal number of cost and time estimates for each activity is twelve. This number almost duplicates for each activity-related risk the user chooses to identify and analyse. Further inputs are required to simulate a project schedule, risk dependencies, pricing mechanisms, etc. The total number of inputs is dependent upon the particular contract strategy that is under evaluation and the level of detail at which a user prefers to define and simulate a project and contract strategy. However, it should also be acknowledged that the aim is to compare contract strategies that are regarded as the most plausible for a given project. Therefore the data-demand escalates further because it is urged that all of the input data steps featured in Figure 5.10 are repeated for each contract strategy that is regarded as an appropriate option and where its analysis is expected to provide insights.

STEP 1

- Establish the number of work packages
- Assign a name to the contractor responsible for each work package
- Specify pricing mechanism type if option selected for any work package
- Specify tender process type if option selected for any work package
- Specify management/consultant's fee type if option selected for any work package

↓

STEP 2

- Specify activities within each work package
- For each activity, specify more than one specific risk or opt to assess the general activity-risk
- Specify the owner of each risk

↓

STEP 3

- Estimate the base cost and base duration for each activity
- (for each risk specified for the activity) estimate the additional cost and delay if the risk occurs at 0%, 25%, 50%, 75% and 100% of the maximum risk level occurrence
- (for each risk specified for the activity) estimate the most likely quarterly risk level

↓

STEP 4

Estimate Spearman's rank order correlation coefficients to represent any risk dependencies

↓

STEP 5

Estimate the project schedule (i.e. activity links)

↓

STEP 6

- Estimate relevant tender bid parameters if pricing mechanism option selected for any work package
- Estimate relevant management/consultant's fee parameters if option selected for any work package

↓

STEP 7 (optional)

- Specify the timing of the client's payments for each work package
- Specify the client's net annual income from the completed project and the time period over which this income is received
- Estimate discount rate

Figure 5.10 Seven steps of model inputs for each evaluated contract strategy

It is evident that the application of the refined model is not a trivial task. In fact the cost, time and effort involved in its application may be regarded as comparable with that involved in the preparation of a tender bid or in a project appraisal before sanction.

The high data requirement raises concerns about the practicality of the model. These concerns are heightened in light of the fact that a client typically faces considerable financial and time-related pressures at the outset of a project which is when the quantitative approach is to be applied.

The timing at which the quantitative approach is to be applied also raises concerns about the feasibility of the quantitative approach. This is because there may be insufficient information available about a project at its outset to enable a model-user to ascertain cost and time values that reflect the potential impact of a contract strategy. The limited amount of information adds to the uncertainty and subjectivity in the decision-maker's imperfect knowledge upon which input estimates are based.

The reliability of the analysis will always be subject to criticism, especially the output to the refined model because it is the accumulated product of a large number of estimates, all of which are highly subjective. However, it is intended that the rigorous, structured and explicit nature of the quantitative approach enables the criticism and debate to be directed to the theories and assumptions that underlie the model inputs and outputs. It is believed that this may lead to less subjective contract strategy decisions.

5.4 Model output

The prototype model's output, for each evaluated contract strategy, includes a distribution of project price and duration values. This chapter has described and justified the model refinements which generate additional model output.

Once all of the values are inputted for a given contract strategy, the refined model performs either 100, 500 or 1000 simulated runs of the project. The subsequent model output includes simulated values of:

- project price;
- project duration;
- net present value of project price and revenue;
- any management/consultant's fee;
- price for each work package; and
- financial outcome of a work package contractor if a pricing mechanism was simulated for the work package.

Section 3.3.3 presented a series of statistical techniques which may be used to interpret the output (see Table 3.12). It is crucial, however, to appreciate that the model output is far from objective. The output represents the estimator's accumulated assumptions about each contract strategy's appropriateness for the project in question.

Many of the industrialists who participated in the empirical study expressed their reservations about the quantitative approach by making reference to the subjectivity of the output. In defence, the quantitative approach is, foremost, a methodology. As such, the purpose of the model inputs is not solely to arrive at the model output.

The process of applying the quantitative approach is intended to improve upon the industry's conventional approach to contract strategy selection. This is because application of the quantitative approach:

- imposes a structure to contract strategy evaluation;
- requires the decision-maker to evaluate contract strategies in terms of cost and time and thus contract strategy alternatives may be compared on a consistent basis and in direct relation to the client's primary objectives (i.e. price and time targets);
- makes the decision-maker's assumptions about the relative appropriateness of contract strategies explicit and therefore open to debate and challenge; and
- enables any relevant case-specific details to be incorporated into the evaluation process.

The results of an application of the quantitative approach provide an indication of the relative appropriateness of each evaluated contract strategy. For example, it is possible to obtain a measure of the likelihood that the client's price and time objectives will be met and whether a particular contract strategy is likely to provide the contractor with an acceptable balance between profit incentive and protection against financial loss.

In addition, the output permits the decision-maker to review the consistency between his/her discrete assumptions and the accumulation of these assumptions. In effect, the quantitative approach tests the decision-maker's assumptions and theories. Furthermore, the quantitative approach facilitates iterative analyses. It is possible to investigate 'what-if' type questions. For example, one could examine the effect that different risk allocations, different cost and time estimates, different project schedules, etc. have on the output.

Chapter 6 presents two example applications of the refined model. Guidance is provided on how to apply the model and how its output may be interpreted. The examples reiterate the fact that the inputs are intended to provide the decision-maker with as much insight as the output.

6. Example applications of the refined model

Chapter 5 described the refined version of the model that facilitates application of a quantitative approach to contract strategy evaluation. In this chapter the refined model is applied to two example projects. The first is a tunnel project and the second involves a factory building with offices.

The two example projects are fictional. They have been fashioned to demonstrate how to apply the model and suggest how its application could aid contract strategy selection.

It is impossible to create very specific project circumstances. Consequently, details of each project focus upon the most relevant issues. In addition, it is necessary to describe the model application from the perspective of a fictional contract strategy selector and/or client.

The first example project has been specifically chosen to demonstrate the capacity of the model to analyse project risks. The model is used to evaluate two contract strategies of converse risk allocations.

In the second example project, prospective contract strategies are evaluated on a more subjective basis. The perceptions of the hypothetical decision-maker are reflected in his/her estimates of each contract strategy's set of cost and time elements for the factory building project.

6.1 Example Project 1: The Tunnel Project

An experienced client has sanctioned a tunnel project. The client's feasibility study identified several key risks and provided sufficient information to analyse these risks. The project is expected to cost the client approximately £14million and the completion date is expected approximately 20 weeks after commencement of the design.

6.1.1 Initial overview of contract strategy selection

For the purposes of this example it was assumed that the client expressed a preference to use its own in-house team to assume an overall project management role. The principal functions of this role include the development of the client's brief, contract strategy selection and project supervision.

It was also assumed that the design would be relatively straightforward once the client's in-house team had prescribed the essential design specifications in the project brief. As a consequence, a Design-Build type arrangement appeared appropriate. The simple design requirements were also assumed to favour a competitive tender process.

Decisions pertaining to risk allocation appeared to warrant particular attention. Therefore, to begin with, it was decided to compare two contract strategies with converse risk allocations.

These two contract strategies both comprise a Design-Build type arrangement which is let on a competitive basis. The differences between the two contract strategies are summarised as follows:

- *Contract Strategy 1 (FP):* all design and construction risks are allocated to the appointed contractor and the contractor is paid on a fixed price basis.
- *Contract Strategy 2 (CP):* all design and construction risks are allocated to the client and the appointed contractor is paid on a cost plus fixed fee basis.

The first contract strategy is to be referred to, hereafter, as FP (i.e. a reference to its fixed price type pricing mechanism). Meanwhile the second contract strategy is to be referred to, hereafter, as CP (i.e. a reference to its cost plus fixed fee type pricing mechanism).

6.1.2 The model inputs for the contract strategy FP

Figure 5.10 presented the series of steps involved in the specification of a contract strategy's model inputs. The titles of the following sub-sections correspond to the steps featured in Figure 5.10.

6.1.2.1 Step 1: Specification of general details regarding the contract strategy's work packages

FP comprises two work packages. One work package constitutes the client's role as the overall project manager. The other work package involves the design and construction of the tunnel. This second work package is to be carried out by the 'yet to be appointed' contractor which has been assigned the label of "Contractor". These details were input into the model using the format shown in Figure 6.1.

The tick marks under the headings 'tender process' and 'pricing mechanism' for work package 2 indicate that the type of tender process and pricing mechanism for this work package is to be accounted for in the analysis. The model subsequently prompted the specification of the type of tender process and pricing mechanism for work package 2. The tender process was specified as 'Competitive'. The pricing mechanism was specified as 'Fixed Price'.

Work package number	Contracting party label	Tender process	Pricing mechanism
1	client	☐	☐
2	Contractor	☑	☑

Figure 6.1 The general work package details inputted into the model

6.1.2.2 Step2: Specification of the activities, risks and risk owners within each work package

The activities listed in Table 6.1 were considered an appropriate breakdown of each work package. The option was taken to analyse the general risks associated with the majority of the activities. Specific risks were identified for two activities (i.e. Boring and Lining). Table 6.1 also shows that all of the risks related to production activities are owned by the contractor under FP.

6.1.2.3 Step 3: Quantification of activities and risks

Section 5.1.2 described the technique used to quantify the specified activities and risks. The estimates for all of the identified activities and risks for FP are displayed in Table 6.2. The base cost and base duration of each activity are shown as a proportion of the overall base cost and duration respectively.

6.1.2.4 Step 4: Specification of correlation between risks

For the tunnel project, it was assumed that none of the risks were strongly correlated to each other. Owing to the potential size of the 'hard ground' risk, it was decided to account for its correlation with two other risks, the risk of 'machine failure during the boring activity' and the general risk of 'cost and time increases related to the client's project management activity'. The correlation between the risk of 'water ingress during the tunnel boring activity' and the general risk of 'cost and time increases related to the client's project management activity' was also accounted for.

The correlation coefficient values inputted into the matrix to account for these risk dependencies are shown in Figure 6.2. If a cell is left blank the model assumes a correlation coefficient of zero (i.e. the two corresponding risks are independent).

Specification of Risk Dependencies

Activity Name	*Risk Name*	Risk no.	*1.1.0*	*2.1.0*	*2.2.0*	*2.3.0*	*2.4.1*	*2.4.2*	*2.4.3*	*2.5.1*	*2.5.2*	*2.6.0*
project management	general	*1.1.0*	1				0.2	0.2				
tender	general	*2.1.0*		1								
Design	general	*2.2.0*			1							
Enabling works	general	*2.3.0*				1						
Tunnel boring	hard ground	*2.4.1*	0.2				1		0.25			
Tunnel boring	water ingress	*2.4.2*	0.2					1				
Tunnel boring	machine failure	*2.4.3*					0.25		1			
Lining	change design	*2.5.1*								1		
Lining	grout required	*2.5.2*									1	
Finishes	general	*2.6.0*										1

Figure 6.2 The correlation coefficient matrix inputted for FP

	Activity name	General activity-risk		Specific activity risks (name each specific risk)					
		(tick if appropriate)	risk owner	risk name	risk owner	risk name	risk owner	risk name	risk owner
Work package 1									
Activity 1.1	Project mgmt.	✓	client						
Work package 2									
Activity 2.1	Tender	✓	Contractor						
Activity 2.2	Design	✓	Contractor						
Activity 2.3	Enabling wks.	✓	Contractor						
Activity 2.4	Boring			Hard ground	Contractor	Water ingress	Contractor	Machine failure	Contractor
Activity 2.5	Lining			Change design	Contractor	Grout required	Contractor		
Activity 2.6	Finishes	✓	Contractor						

Table 6.1 The activities, risks and the owners of each risk that were specified for the work packages under FP

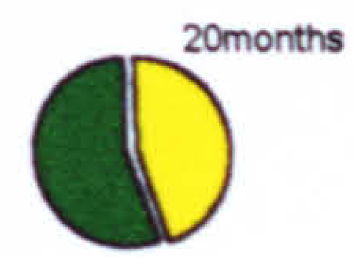
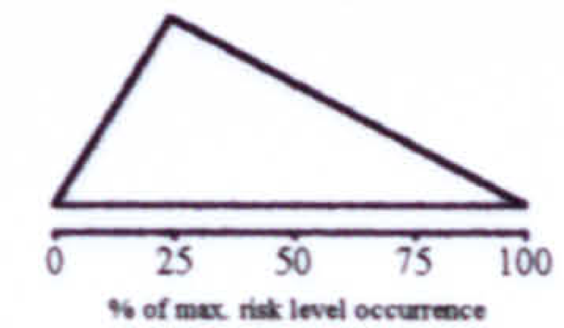
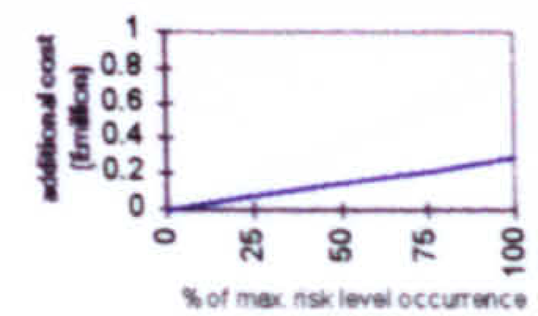
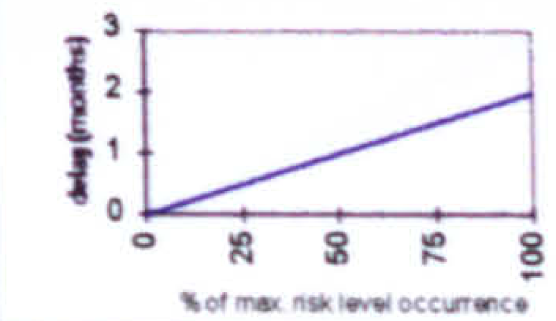
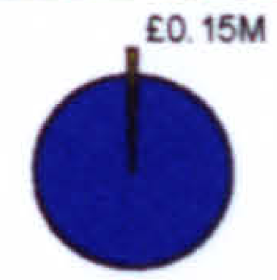
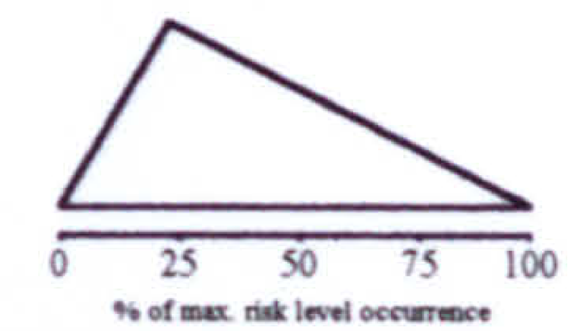
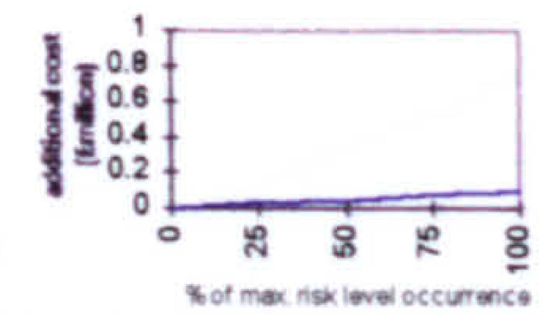
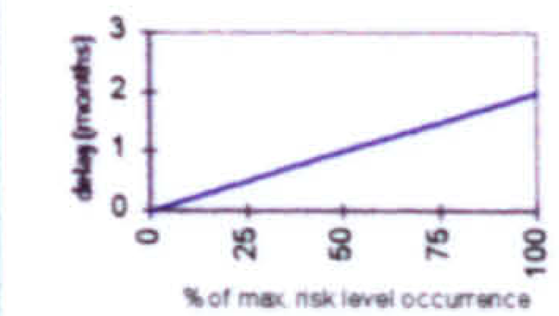
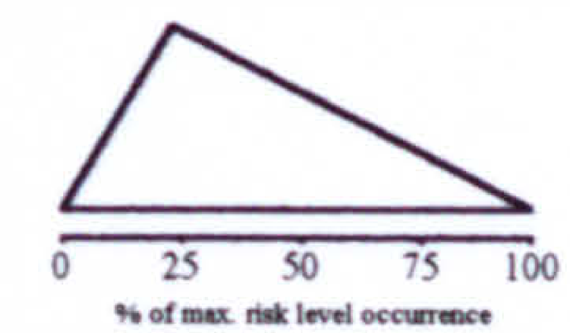
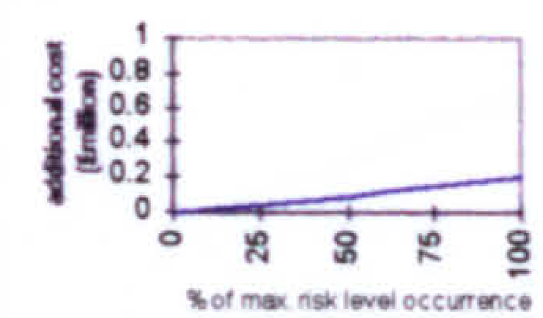
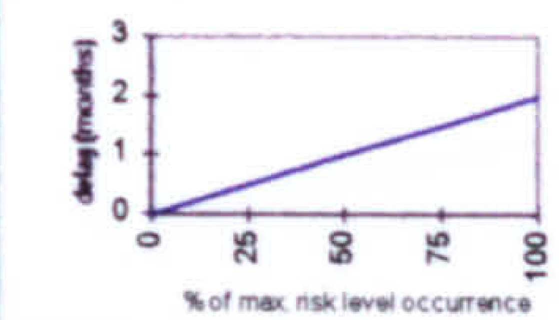
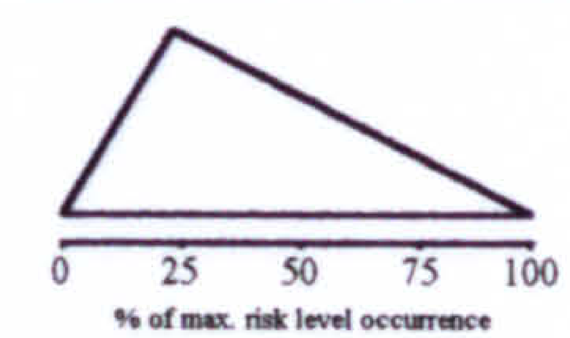
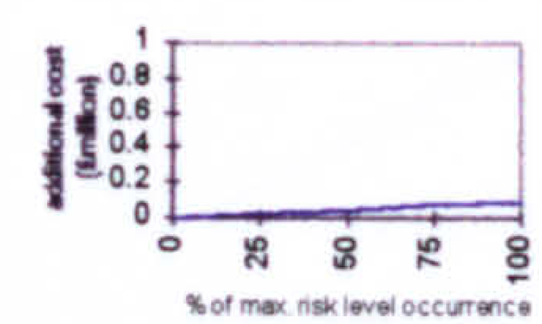
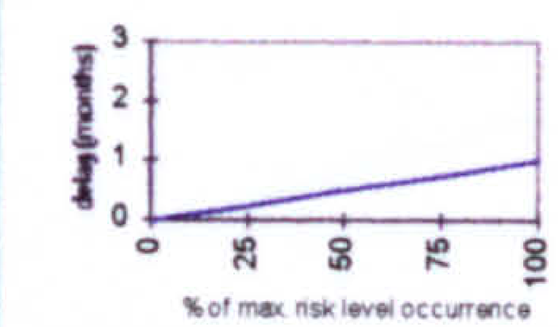
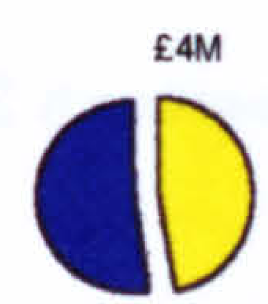
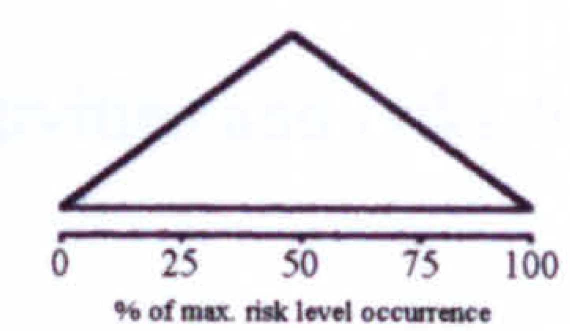
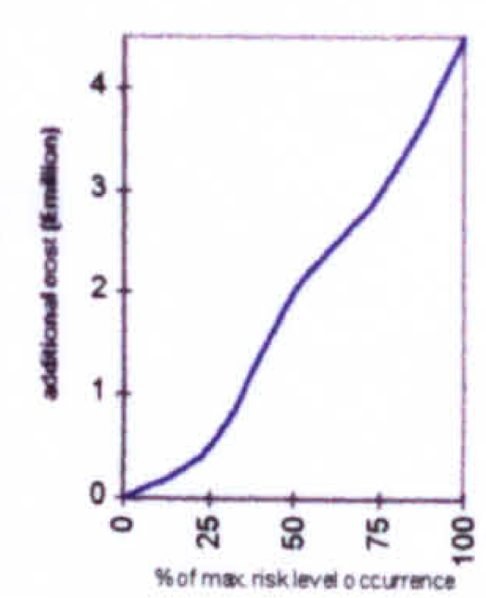
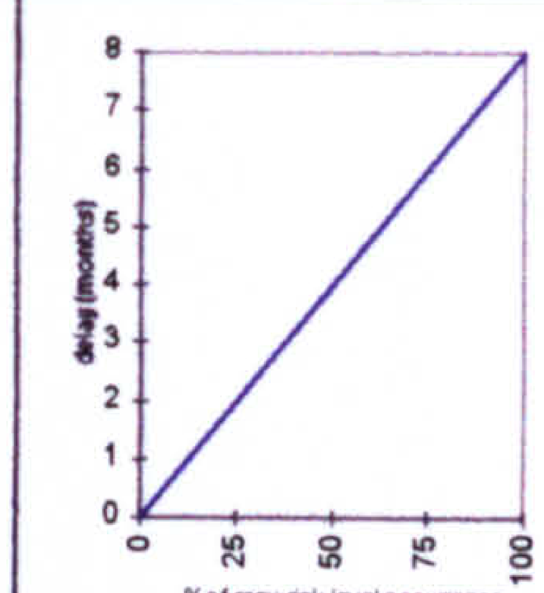
RISK NUMBER & NAME	RISK OWNER	ACTIVITY BASE COST	ACTIVITY BASE DURATION	RISK LEVEL OCCURRENCE PROBABILITY DISTRIBUTION	RISK LEVEL – ADDITIONAL COST RELATIONSHIP	RISK LEVEL – DELAY RELATIONSHIP
1.1.0 general risk (project management activity)	Client					
2.1.0 general risk (tender process activity)	Client					
2.2.0 general risk (design activity)	Contractor					
2.3.0 general risk (enabling works activity)	Contractor					
2.4.1 hard ground	Contractor					

Table 6.2 Quantification of the activities and risks for FP *(continued overleaf)*

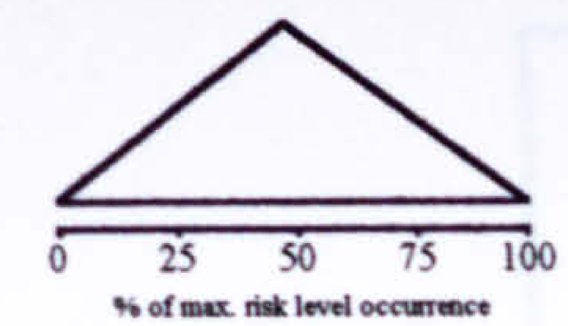
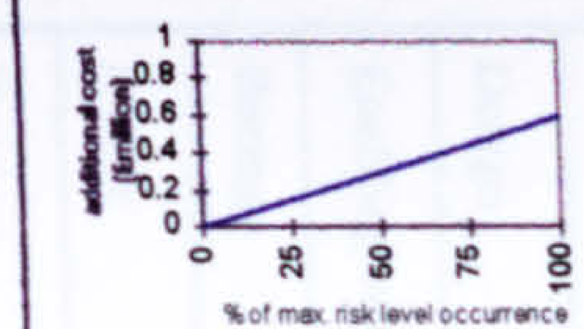
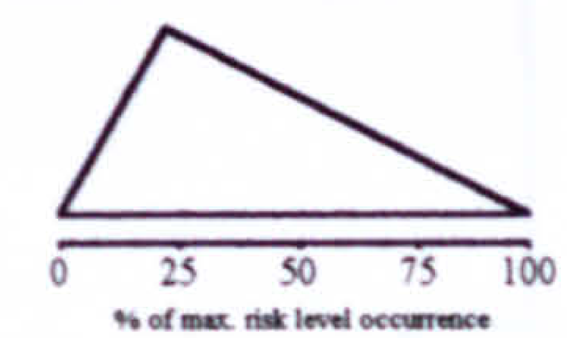
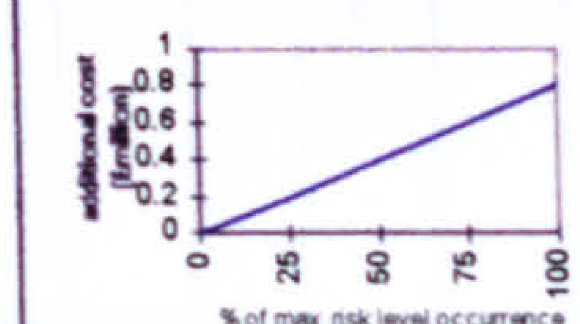
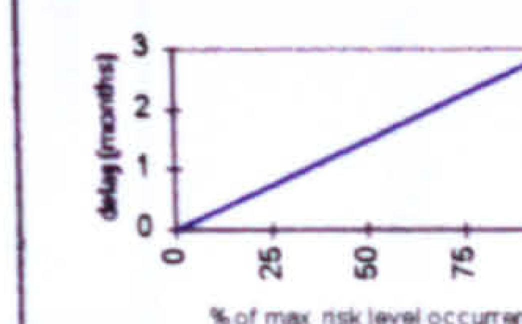
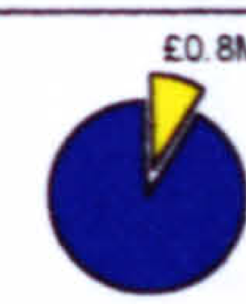
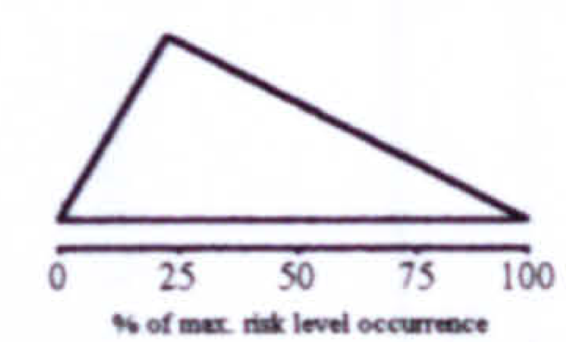
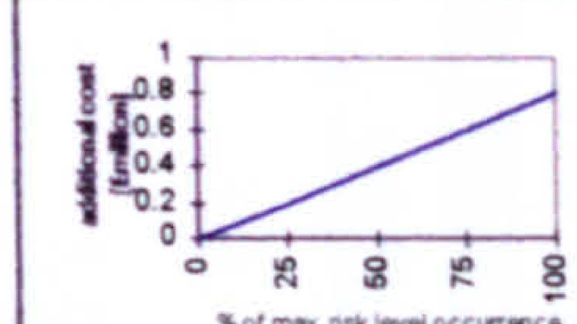
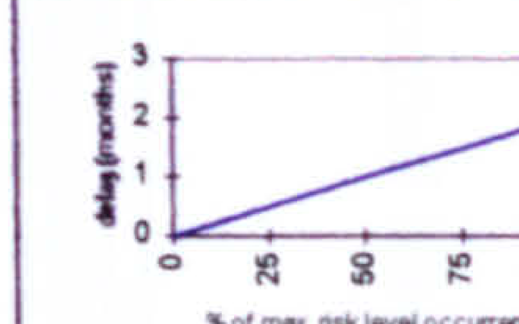
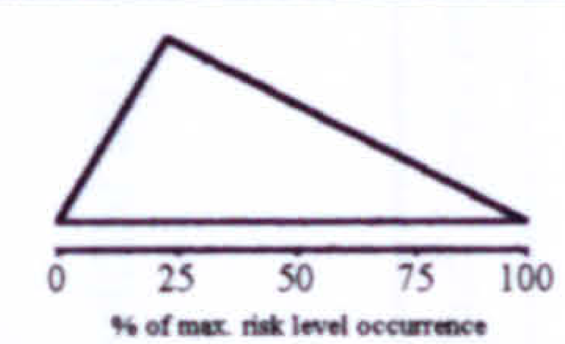
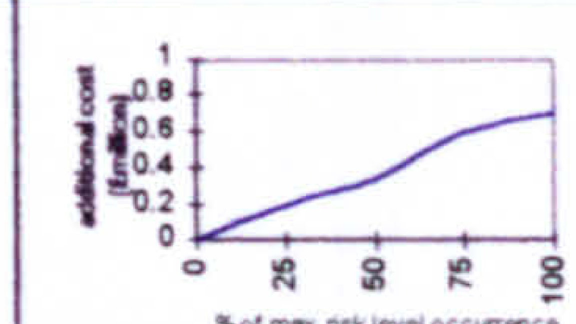
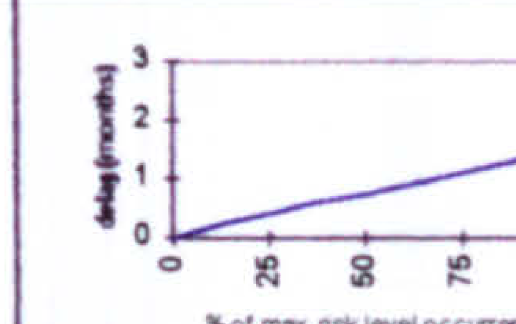
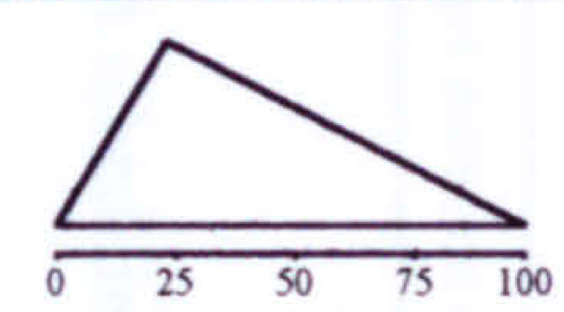
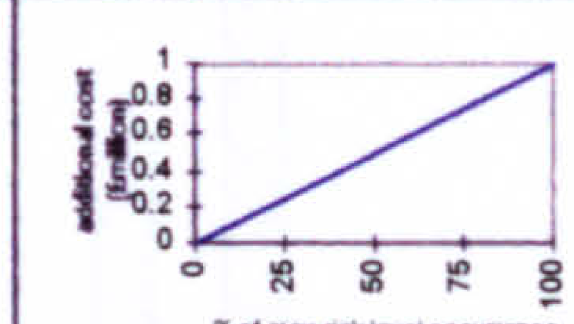
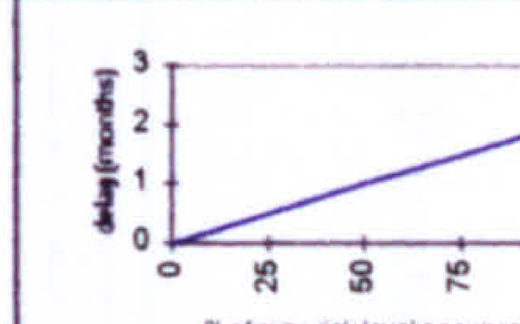
2.4.2 water ingress	Contractor					
2.4.3 machine failure	Contractor					
2.5.1 change design	Contractor					
2.5.2 grout required	Contractor					
2.6.0 general risk (finishes activity)	Contractor					

Table 6.2 *(continued)* Quantification of the activities and risks for FP

6.1.2.5 Step 5: Specification of project schedule

The project schedule inputted into the model for FP is shown in Figure 6.3.

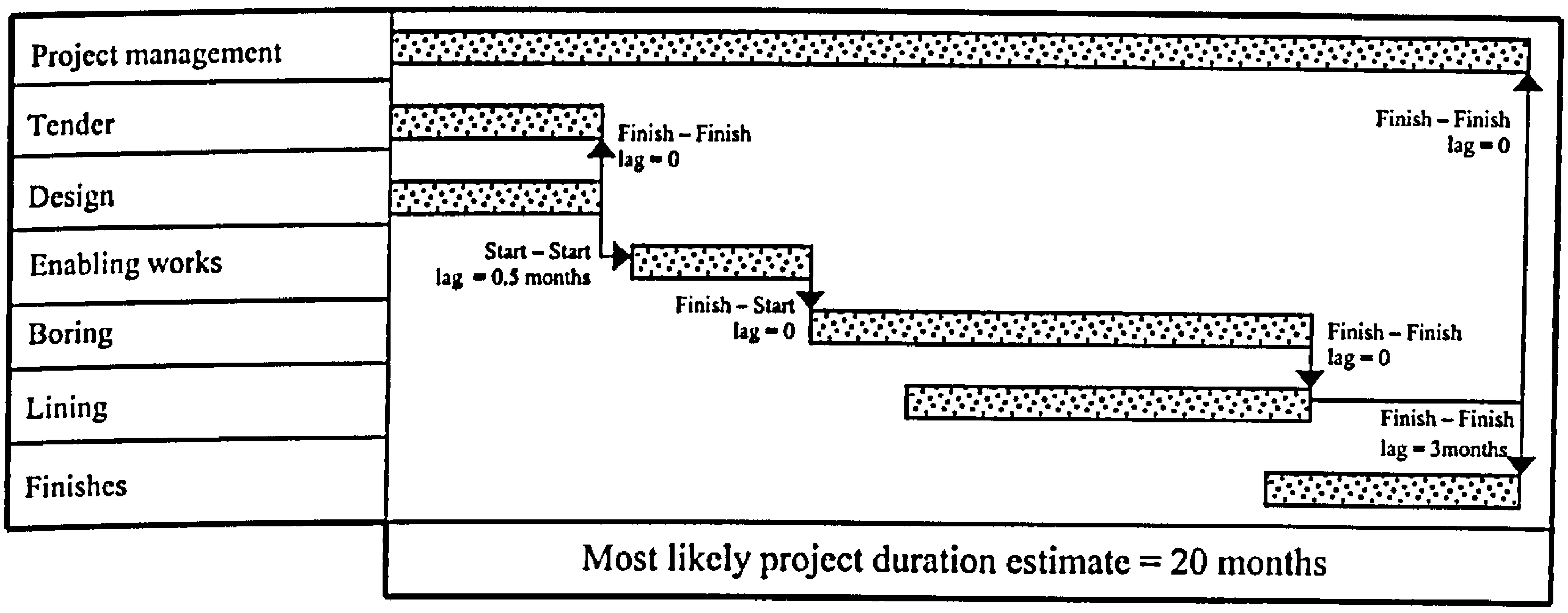


Figure 6.3 The project schedule for FP

6.1.2.6 Step 6: Specification of tender bids

The option to analyse the effect of using a pricing mechanism for work package 2 was selected at the outset. As a result, the model performed Monte Carlo simulation to calculate probability distributions of:

- *The contractor's costs.* This included the base cost of all the activities in work package 2 (£7.9million) and the cost of the risks which are owned by the contractor (see Figure 6.4).
- *The client's costs (for work package 2).* Owing to the inputs made for FP, the client costs for work package 2 included just the costs associated with the tender process activity.

The purpose of calculating and displaying these two distributions is to assist the model-user in the estimation of the tender bids which may be submitted for work package 2. It was specified at the outset that FP utilises a fixed price type pricing mechanism for work package 2. Consequently, whilst displaying the distributions described above, the model prompted the user for inputs of a minimum, most likely and maximum fixed price tender bid for work package 2. These estimated values constitute a triangular probability distribution of fixed price tender bids.

As with all of the other inputs, the model-user must make an assessment which addresses the particular circumstances of the project. However, at a general level, the estimated fixed price levels must aim to:

1. reimburse the contractor for the base cost of all the activities (i.e. cost assuming no risks occur);
2. cover the cost of the risk which the contractor is responsible for;
3. offer the contractor the opportunity to make an adequate level of profit; and
4. be low enough to win the contract against competing contractors.

The calculated distribution of the cost of the work involved in work package 2 is shown in Figure 6.4. The bidding strategy based upon this distribution is outlined below. This bidding strategy is simply a demonstration of the type of reasoning that may be employed in making these inputs. The model allows the user's discretion to be applied.

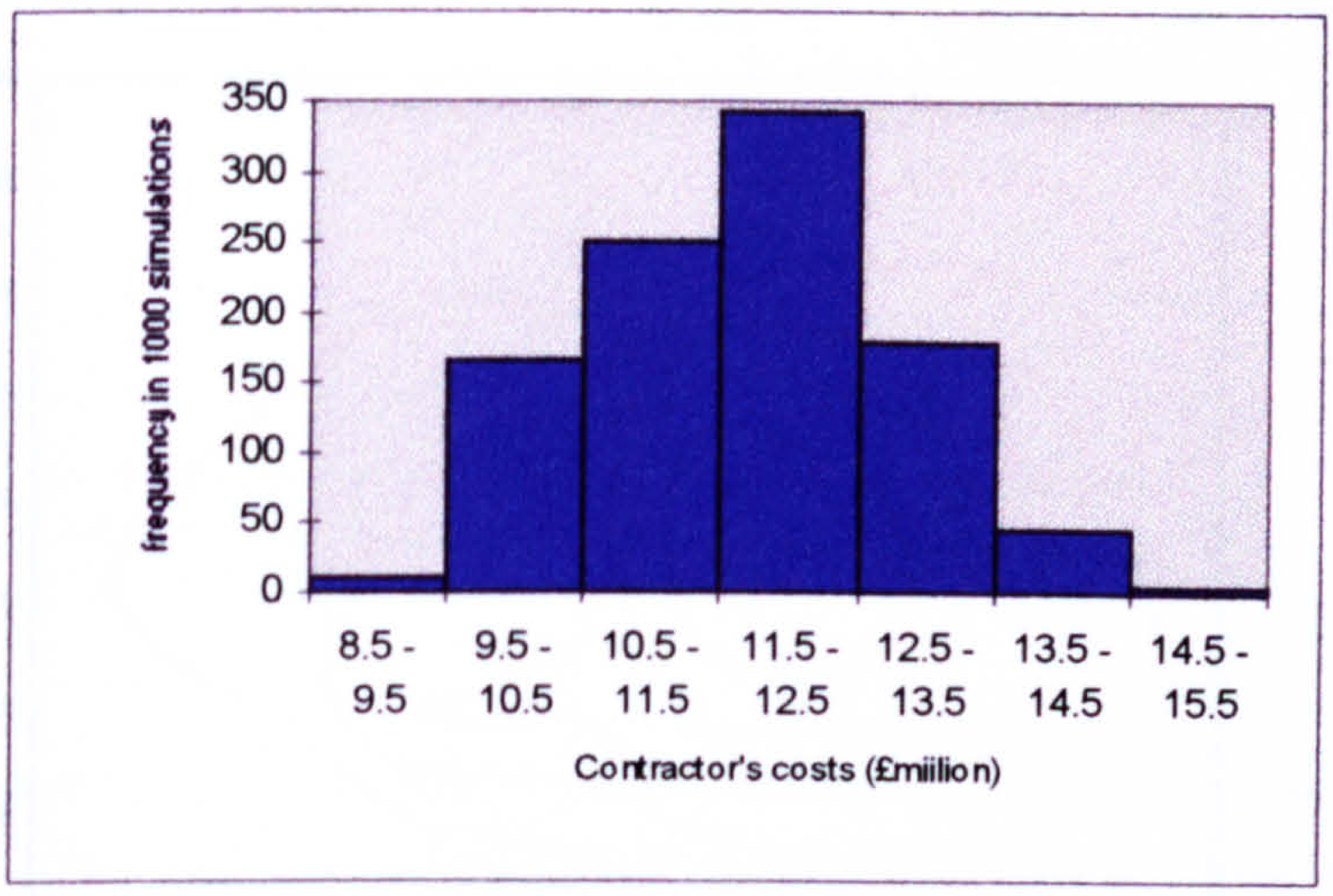


Figure 6.4 The contractor's cost distribution for work package 2

<u>Example fixed price bidding strategy used for FP</u>

Base cost for work package 2 (i.e. costs reimbursed by client) = £7.9M

Most likely cost of the work (derived from the results shown in Figure 6.4) = £12.1M

The distribution of tender bids is estimated as different levels of mark-up added to the most likely cost of the work. These levels of mark-up are specified as percentages of the cost of the work. The mark-up is intended to include an adequate risk premium and a margin of profit.

Minimum fixed price bid	= 1.12 x 12.1 = £13.6M	(i.e. 12% mark-up)
Most likely fixed price bid	= 1.20 x 12.1 = £14.5M	(i.e. 20% mark-up)
Maximum fixed price bid	= 1.22 x 12.1 = £14.8M	(i.e. 22% mark-up)

6.1.3 Model output for contract strategy FP

Once all of the inputs referred to in the preceding sections were made, the model performed Monte Carlo simulation to calculate a set of results for the contract strategy FP. These results represent the price and duration outcomes having simulated the project 1000 times. Figure 6.5 provides a graphical presentation of the model output for FP. These results suggest that if FP was used to procure the tunnel project:

- the price of the project will be between £14.5M and £15.6M;
- the most likely project price will be £15.1M;
- the duration of the project will be between 18months and 25months;
- the most likely project duration will be 21months.

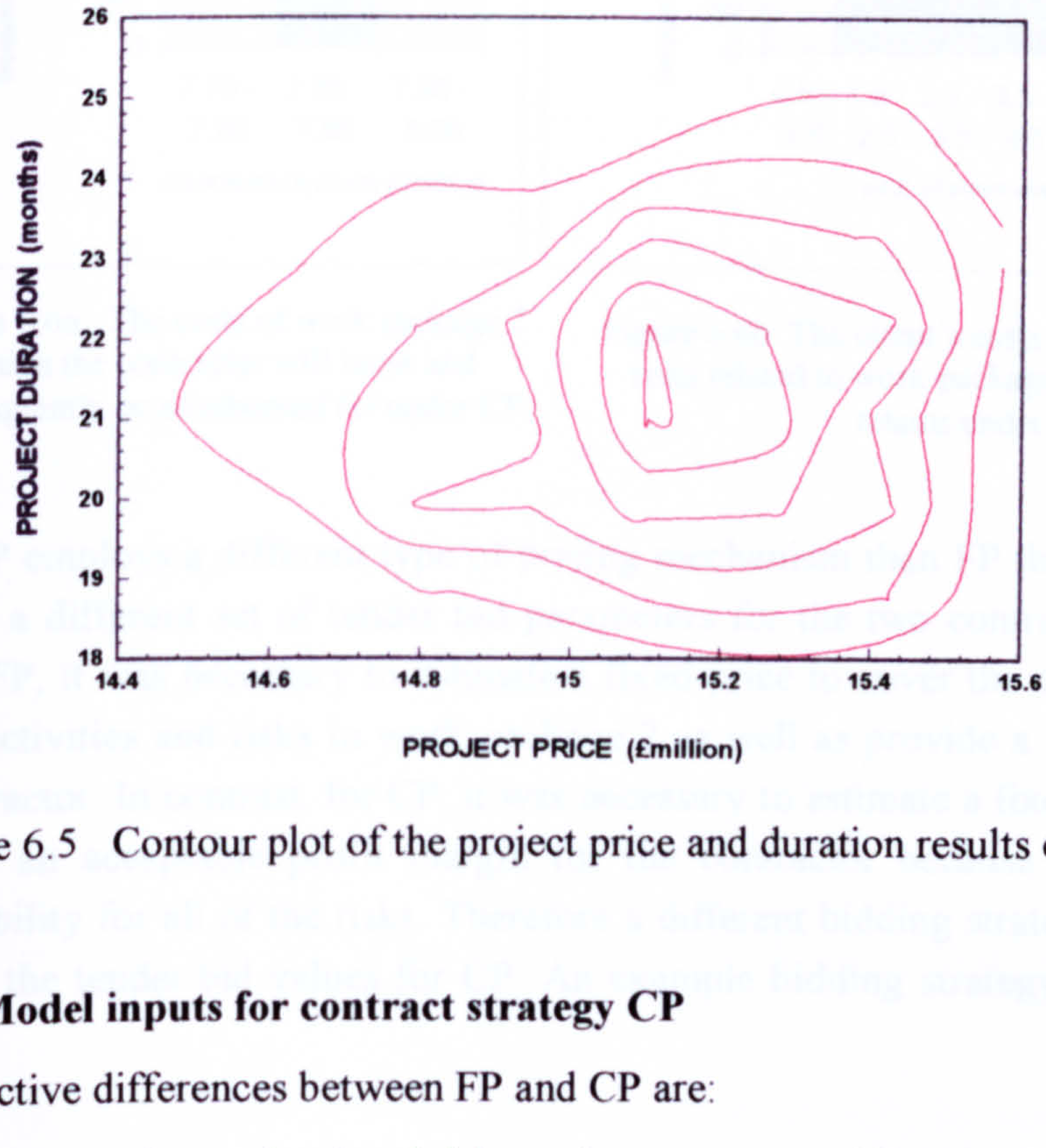


Figure 6.5 Contour plot of the project price and duration results calculated for FP

6.1.4 Model inputs for contract strategy CP

The objective differences between FP and CP are:

1. FP allocates the work-related risks to the contractor while CP allocates these risks to the client; and
2. FP uses a fixed price type pricing mechanism while CP uses a cost plus fixed fee type pricing mechanism.

As a consequence, the model inputs with regards to work breakdown and cost and time estimates for CP were the same, on the whole, as those made for FP. However, for CP, the client was specified as responsible for all the risks in work package 2. In addition, it was necessary to estimate a distribution of fixed fee bids (as opposed to fixed price bids) which competing contractors were likely to submit for work package 2.

6.1.4.1 Step 6: Specification of tender bids

CP allocates the work-related risks to the client. Therefore the contractor is simply reimbursed the base cost of all the activities in work package 2 (i.e. the cost assuming no risks occur). Since the base cost estimates are single value estimates the contractor's cost of work in work package 2 is a single value (see Figure 6.6a). Figure 6.6b is the distribution of the costs which the client is likely to incur for work package 2.

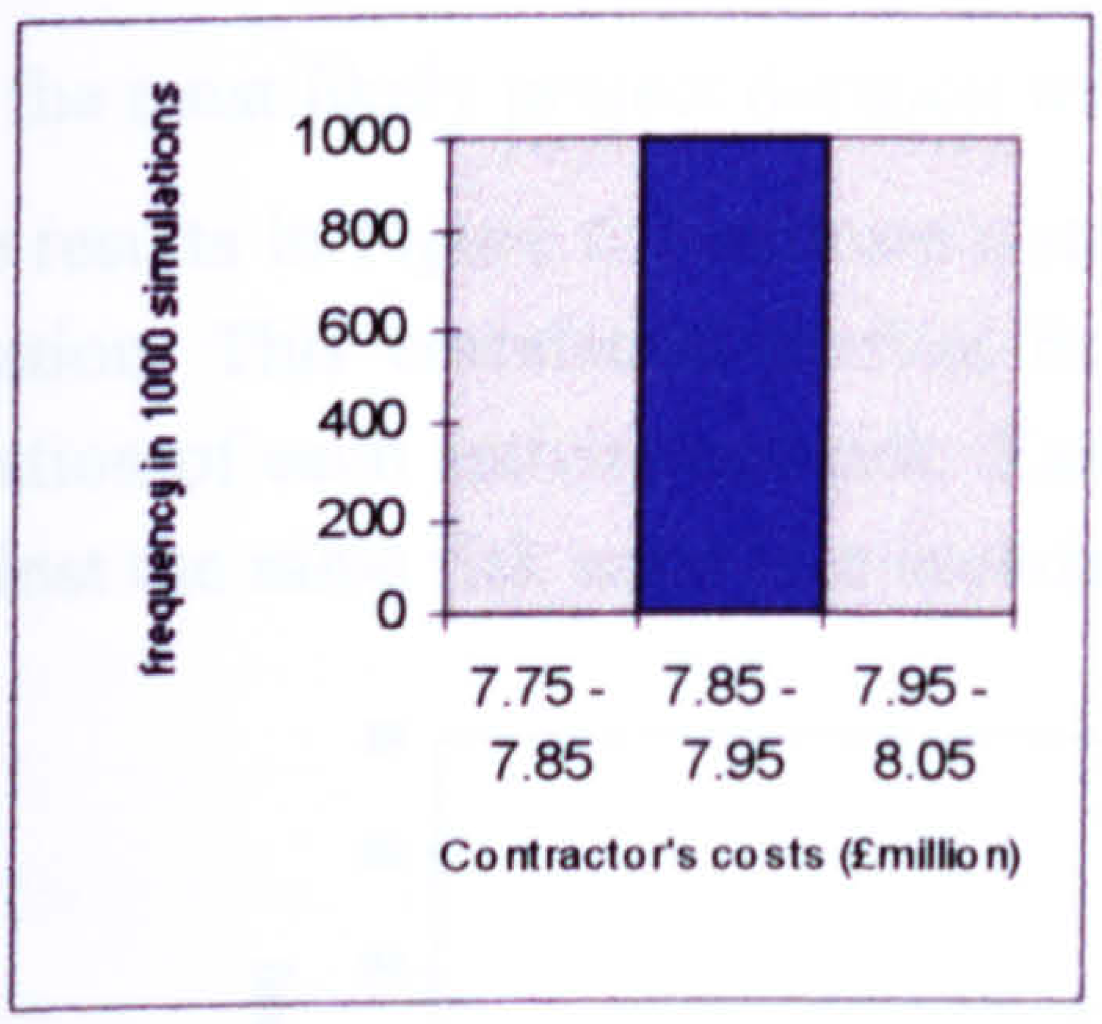


Figure 6.6a The costs of work package 2 which the contractor will incur and subsequently be reimbursed for under CP

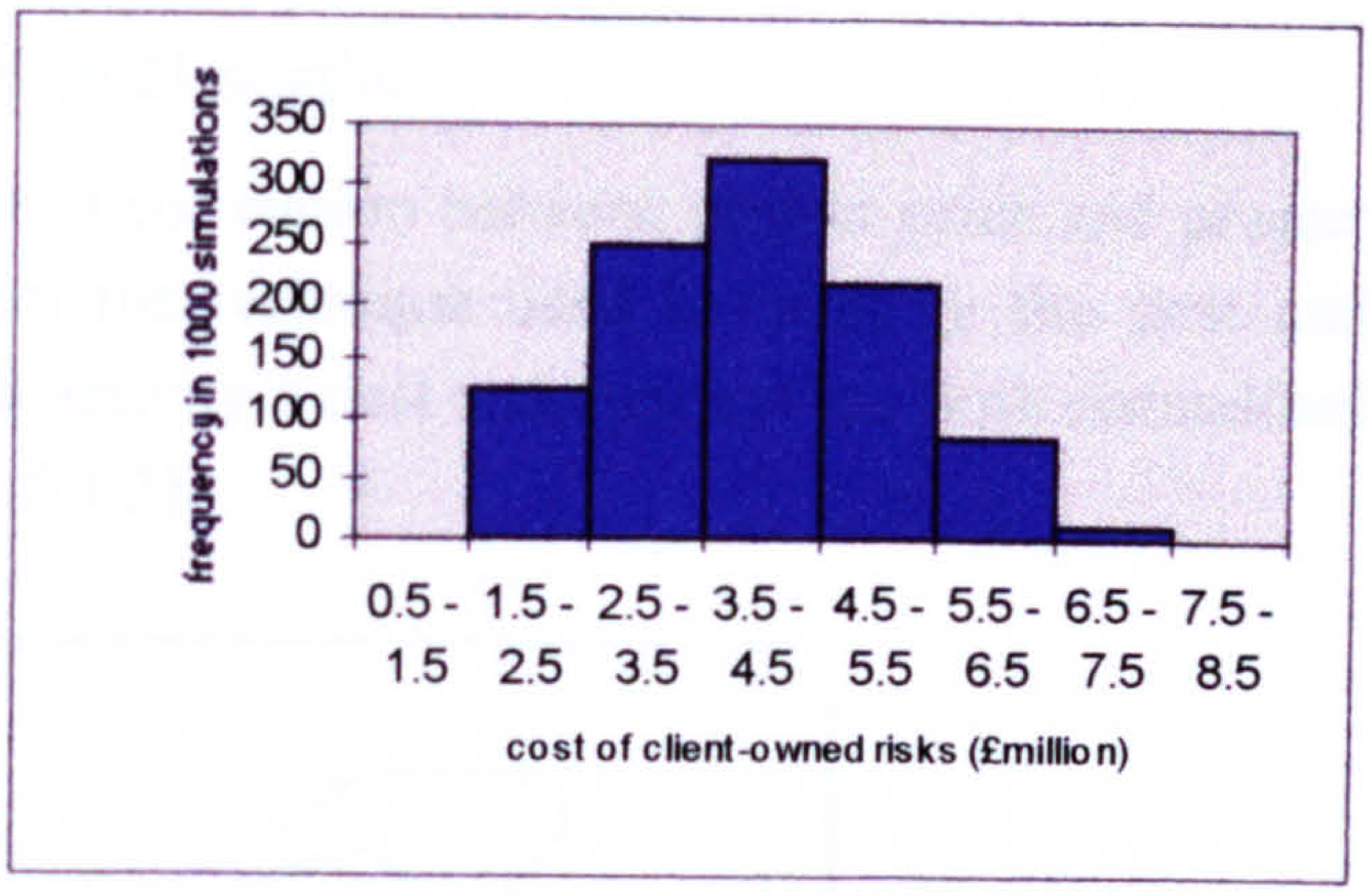


Figure 6.6b The client's costs which arise from the risks related to work package 2 which the client retains under CP

Since CP employs a different type of pricing mechanism than FP the user is required to estimate a different set of tender bid parameters for the two contract strategies. In the case of FP, it was necessary to estimate a fixed price to cover the cost of all the work-related activities and risks in work package 2 as well as provide a margin of profit for the contractor. In contrast, for CP, it was necessary to estimate a fixed fee which simply provides an acceptable profit margin for the contractor because the client assumes responsibility for all of the risks. Therefore a different bidding strategy must be used to estimate the tender bid values for CP. An example bidding strategy for CP is outlined below.

<u>Example cost plus fixed fee bidding strategy used for CP</u>

The cost of the work with which the contractor will be fully reimbursed = £7.9M

The distribution of tender bids are estimated as profit margins. These profit margins are specified as percentages of the cost of the work.

Minimum fixed fee bid	= 0.04 x £7.9M = £0.32M	(i.e. 4% profit margin)
Most likely fixed fee bid	= 0.08 x £7.9M = £0.65M	(i.e. 8% profit margin)
Maximum fixed fee bid	= 0.12 x £7.9M = £0.95M	(i.e. 12% profit margin)

6.1.5 The model output for contract strategy CP

Figure 6.7 provides a graphical presentation of the model output calculated for CP. These results suggest that if CP was used to procure the tunnel project:

- the price of the project will be between £10.2M and £16.2M;
- the most likely project price will be £13.2M;
- the duration of the project will be between 17 months and 25 months;
- the most likely project duration will be 21months.

The results in Figure 6.7 indicate a strong correlation between project price and project duration. This correlation derives from the technique used to quantify the cost and duration of each activity and risk. Each activity's cost and duration are both normalised against the same risk scale (see section 5.1.2).

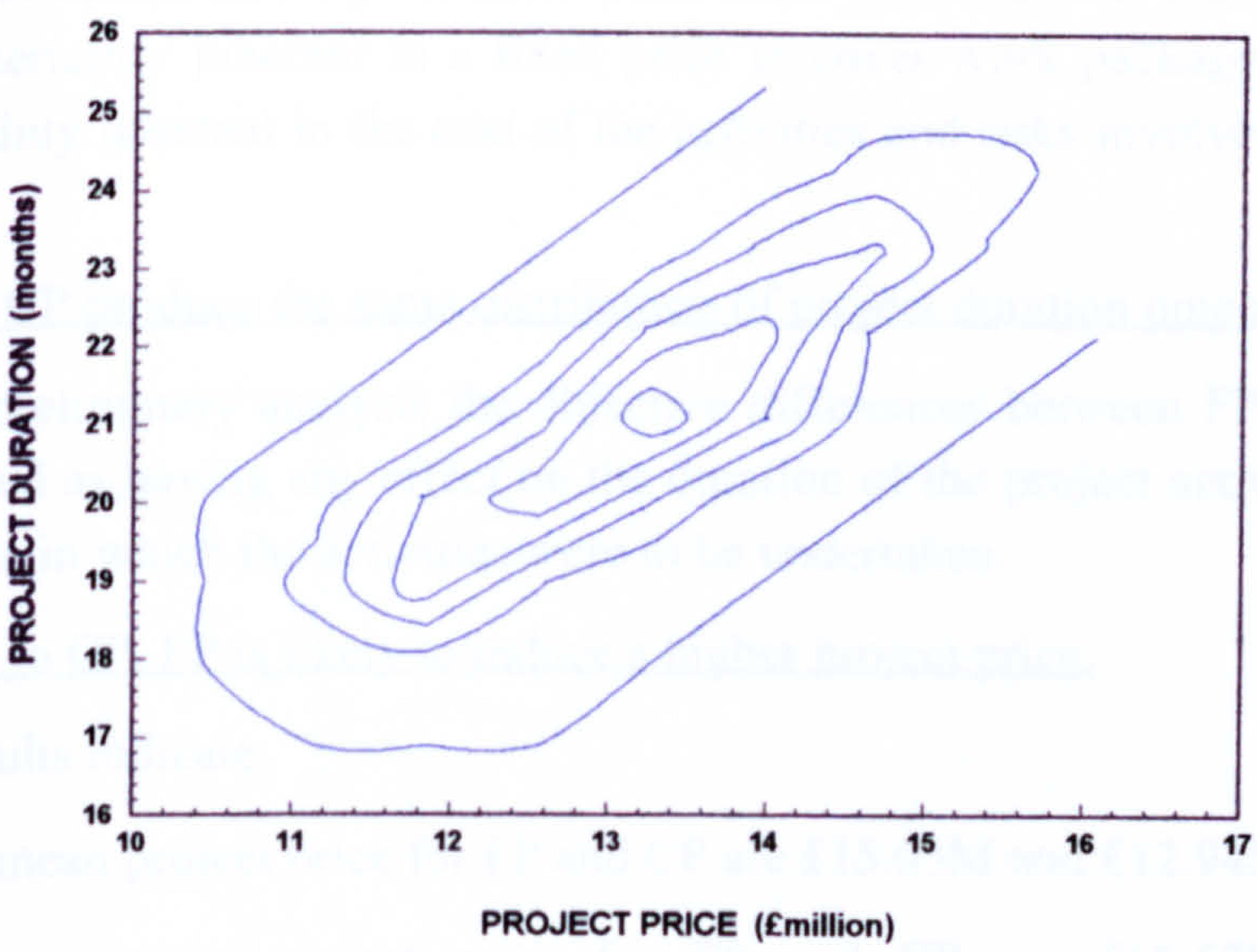


Figure 6.7 Contour plot of the project price and duration results calculated for CP

This correlation is observed in the results calculated for CP, but not in those calculated for FP because of the different types of pricing mechanisms that each contract strategy employs. Since CP uses a cost reimbursable type pricing mechanism, the price paid for work package 2 consists of the actual cost of the work plus a fee. Owing to the technique used to quantify each activity and risk (see section 5.1.2), the actual cost of work package 2 will be incurred within a correlated period of time. Meanwhile, the price fixed for work package 2 under FP is assumed to be independent of the actual cost of the work and consequently independent of the project duration.

6.1.6 Comparison of the results calculated for FP and CP

Figures 6.8 and 6.9 display both sets of results calculated for FP and CP. The results may be interpreted as follows:

1. FP covers a much smaller price range than CP.

   The project price range calculated for CP effectively comprises the range of cost values inputted for all the project activities and the fixed fee bids distribution. In contrast, the project price range calculated for FP comprises the range of cost values inputted for the project management activity and the tender process activity plus the distribution of fixed price bids for work package 2. Therefore, in the case of FP, the range of values estimated for the work-related activities in work package 2 are made redundant by the distribution of fixed price bids estimated for this contract strategy. As a consequence, the range of project price outcomes for FP is largely dependent upon the estimated range of fixed price bids. The results in Figure 6.8 suggest that the uncertainty inherent in a fixed price to cover work package 2 is less than the uncertainty inherent in the cost of the activities and risks involved in work package 2.

2. FP and CP produce the same distribution of project duration outcomes.

   In the preliminary analysis the objective differences between FP and CP were not perceived as having any effect on the duration of the project activities nor upon the schedule in which the activities were to be undertaken.

3. relative to CP, FP is likely to induce a higher project price.

   The results indicate:

   - the mean project price for FP and CP are £15.03M and £12.94M, respectively;
   - the maximum project price for FP and CP are £15.57M and £16.08M, respectively;
   - the minimum project price for FP and CP are £14.32M and £10.44M, respectively;
   - there is a probability of 0.88 that CP will induce a lower project price than the minimum possible price for FP;
   - there is a probability of 0.95 that the contractor's profit for CP will lie between £0.39M and £0.89M (see Figure 6.9);
   - FP presents the contractor with a 0.005 probability of making a loss (the maximum loss was calculated at £0.04M);
   - FP presents the contractor with a 0.93 probability of making a profit which exceeds £1M.

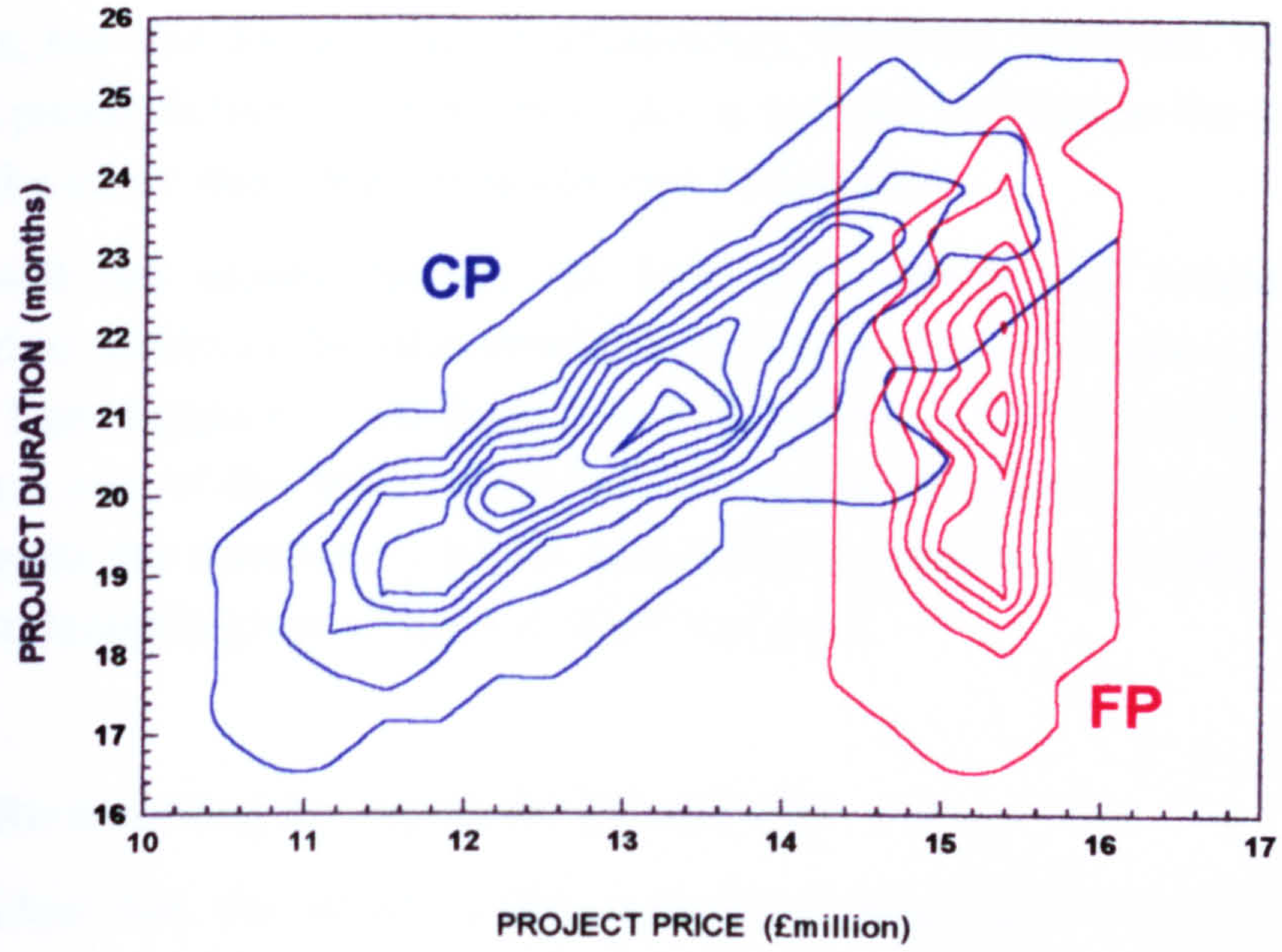


Figure 6.8 Comparison of the price and duration results calculated for FP and CP

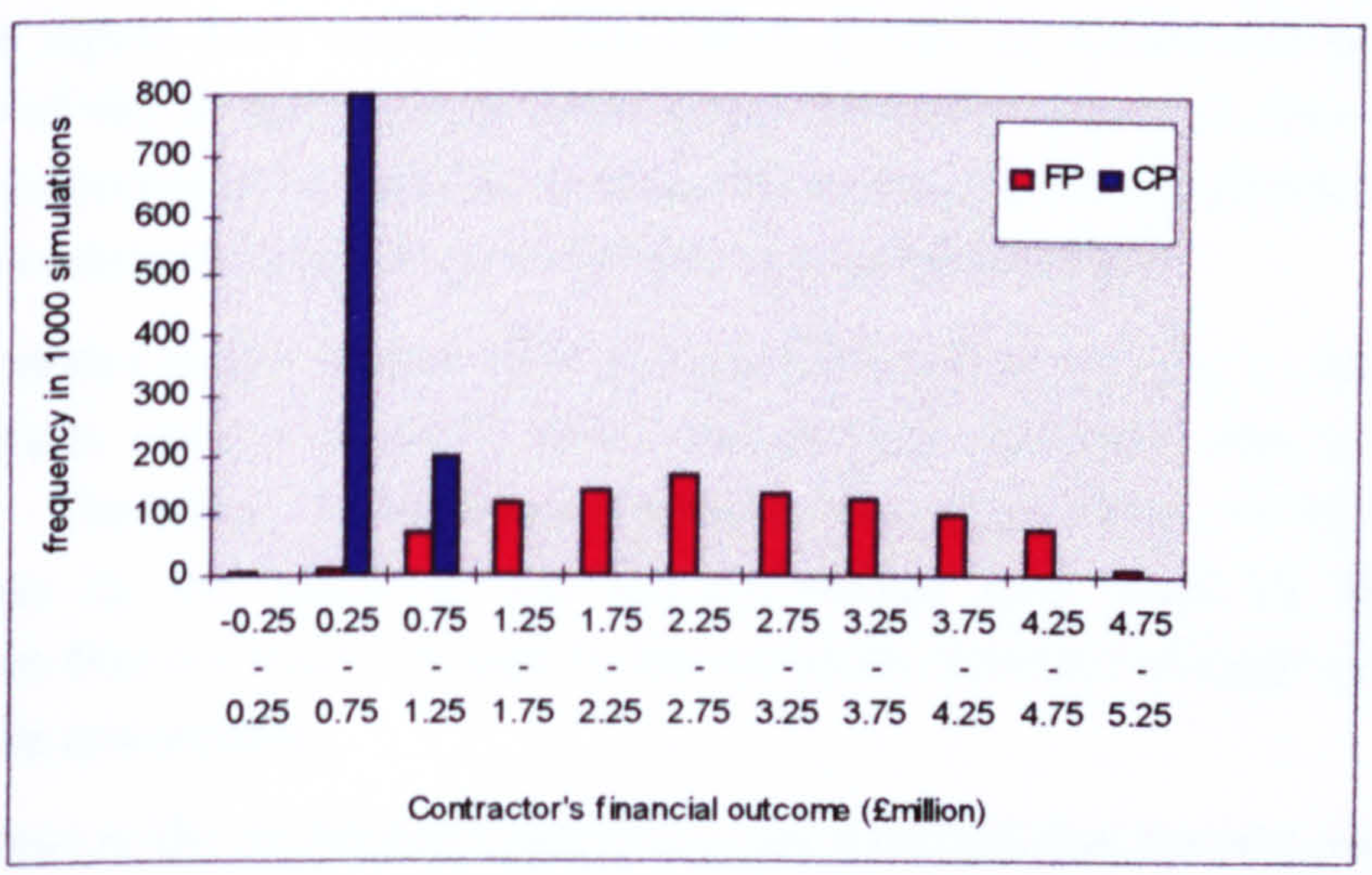


Figure 6.9 Comparison of the contractor's outcome calculated for FP and CP

The only differences between FP and CP that were accounted for in the analysis were their different risk allocation and type of pricing mechanism (i.e. only objective differences). The allocation of risks to the client under CP means that the client would pay the actual cost of the risks. The spread of the results calculated for CP (Figure 6.8) illustrates that considerable uncertainty surrounds the actual cost of the risks. If FP was used the client effectively pays the contractor a premium, established at the tender stage (i.e. before the risks occur), so that the contractor assumes responsibility for the risks and pays their actual costs. Therefore the client avoids not only paying the actual cost of the risks, but also the uncertainty surrounding their cost. However, Figure 6.8 indicates that the premium that the client must pay to transfer the risks to the contractor is likely to cost the client more than the actual cost of the risks.

This result has ensued because the fixed price tender bids estimated for FP were intended to minimise the likelihood that the contractor will make a financial loss. It is evident from Figure 6.9 that this has been achieved. However, in those instances where the actual cost of the risks is less than its maximum possible level, the risk premium supplements the contractor's profit. As a result the contractor's profit under FP is likely to be substantially greater than that if CP was used.

6.1.7 Re-assessing the inputs for FP and CP

It is evident that the model is able to produce meaningful results that could aid the decision process. However, when interpreting the results, it is crucial for the decision-maker to appreciate their origin. The results are a product of the input estimates and the subjective assumptions that underlie these estimates.

If particular inputs are recognised as having considerable impact upon the model output or if some inputs were especially speculative it may be worthwhile to investigate the sensitivity of the model output to these inputs. However, one must bear in mind that the inputs are expected to be intuitive because the analysis is being carried out at the project outset and contract strategies are evaluated on a subjective basis.

Since the model output cannot offer any guarantees with regards to contract strategies' actual impacts upon a project's price and duration one must aim to use the model efficiently. Therefore, rather than assessing the implications of all the subjective assumptions in the analysis, the decision-maker may need to focus upon the assumptions that are most relevant to the particular contract strategy decision problem that is under assessment.

For the inputs in the preliminary analysis it was assumed that the two contract strategies would not have any distinguishing cost and time effects on the project activities and risks. However, the quantitative approach is designed to enable a decision-maker to account for subjective assumptions about contract strategies' anticipated cost and time effects.

Subjective distinctions between FP and CP that could be incorporated into the analysis include:

- The base cost of the project management activity could be increased for CP relative to that for FP. This is to reflect the possibility that the client will expend more resources on cost monitoring for CP than FP because CP uses a cost reimbursable type pricing mechanism and allocates the project risks to the client.

- The base cost of the project management activity could be increased for FP relative to that for CP. This is to reflect the possibility that the client may expend more resources to supervise the contractor's work if FP is used. This is because FP places the contractor under a great deal of financial risk and the client does not want this to lead to a deterioration in quality standards.
- The base duration of all the activities in work package 2 could be decreased for FP relative to CP. The justification for this relative reduction derives from the assumption that, compared to CP, FP provides the contractor with a greater incentive to sustain a higher productivity rate.

It was perceived, however, that a more significant subjective distinction between FP and CP warranted quantification: impact of risk control measures. The following section addresses this issue.

6.1.7.1 Modelling the impact of risk control measures

The objective differences between FP and CP are:

1. FP allocates the work-related risks of work package 2 to the contractor while CP allocates these risks to the client; and
2. FP requires the contractor to fix the price of work package 2 before the work has commenced. In contrast, if CP is used, the client fully reimburses the contractor's actual costs incurred for work package 2 and the contractor receives an additional fee. The fee must be fixed before the work is commenced.

One could perceive that, owing to these differences, FP is likely to induce more effective management of the risks in work package 2. This subjective assumption could be justified as follows:

1. FP allocates the risks in work package 2 to the party which can best control them (i.e. the contractor); and
2. FP provides the contractor with more incentive to minimise the cost of the risks. This is because the fixed price type pricing mechanism governs that the contractor's profit increases if the cost of the risks is minimised.

These subjective assumptions suggest that the inputs for CP should remain the same as those estimated in the preliminary analysis, while the inputs for FP should be modified to reflect the anticipated reduction in risks if FP was used.

To begin with, it was necessary to identify which risks may be reduced by the contractor's implementation of effective control measures. Table 6.3 lists the identified risks and indicates the measures that may reduce the cost and delay associated with these risks.

Project Risk	Risk reduction strategy
Hard ground (risk no. 2.4.1) (related to tunnel boring activity)	1. Standby blasting 2. Advance probing 3. Alternative cutters
Water ingress (risk no. 2.4.2) (related to tunnel boring activity)	1. Install advance de-watering 2. Grouting systems on standby 3. Potential for compressed air 4. Drive uphill 5. Pumps on standby
Machine failure (risk no. 2.4.3) (related to tunnel boring activity)	1. Additional fitters 2. Standby components
Grout required (risk no. 2.5.2) (related to tunnel lining activity)	1. Grout kit on-site 2. Personnel and equipment on standby

Table 6.3 The risk reduction measures which may induce cost and time savings under FP

It was expected that the implementation of risk-reducing measures would increase the base cost and base duration of the respective activities. Figure 6.10 presents the adjustments made to the inputs for the risk of 'grout required during tunnel lining'. The modified inputs for the other risks are displayed in Table 6.4.

Work package number:	2
Activity number:	2.5
Activity name:	Lining
Risk number:	2.5.2
Risk name:	Grout required
Party responsible for the risk:	contractor

	Original estimates	Revised estimates
Activity's base cost:	**£0.75M**	**£0.80M**
Activity's base duration:	**6 months**	**6 months**

Quarterly risk level	Most likely risk level (tick appropriate risk level)		Additional cost (£M) (to the activity's base cost)		Delay (months) (to the activity's base duration)	
Negligible (0%)			0	0	0	0
Marginal (25%)	√	√	0.20	0.13	0.40	0.25
Serious (50%)			0.35	0.25	0.75	0.50
Severe (75%)			0.60	0.38	1.10	0.75
Critical (100%)			0.70	0.50	1.50	1.00

Key: Original estimates (shaded)   Revised estimates (unshaded)

Figure 6.10 Revised quantification of the 'Grout required' risk for FP

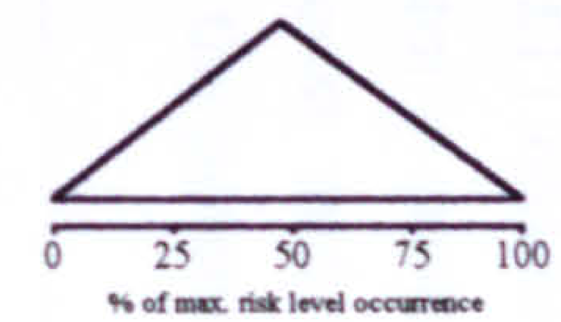
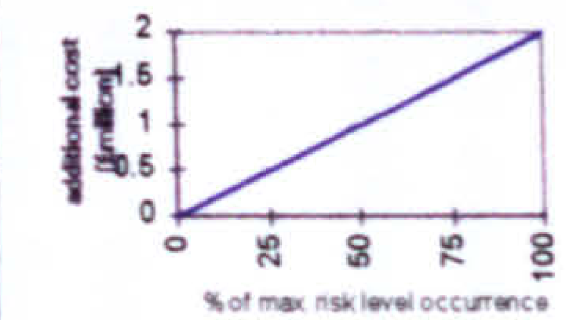
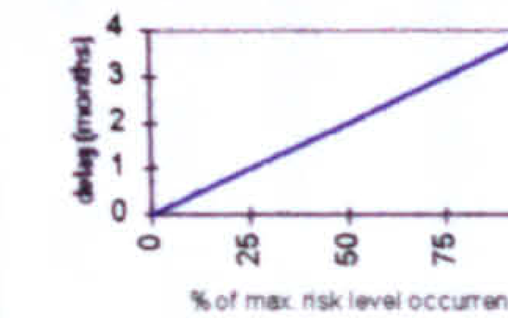
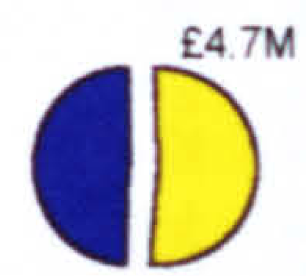
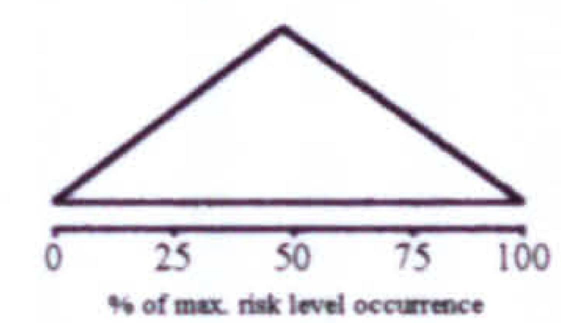
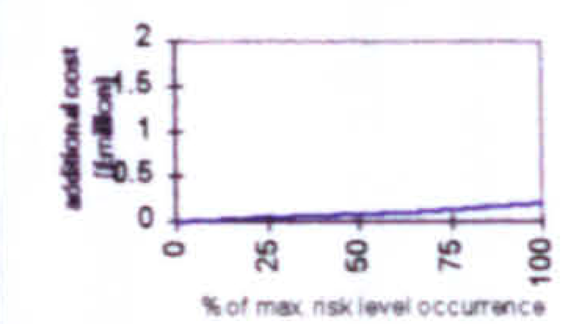
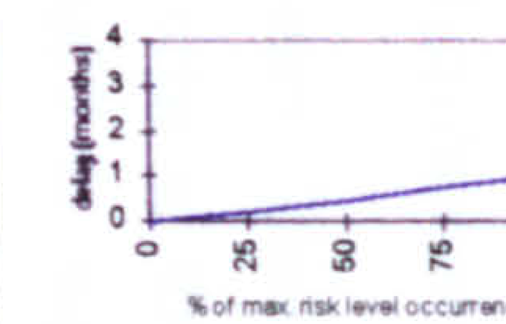
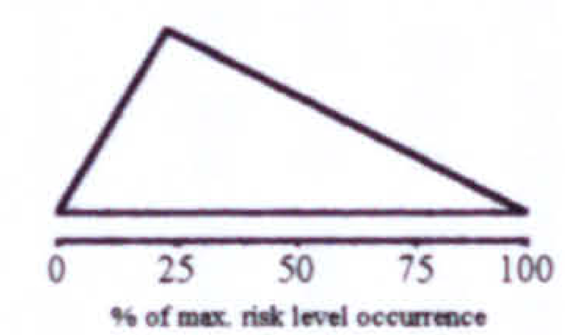
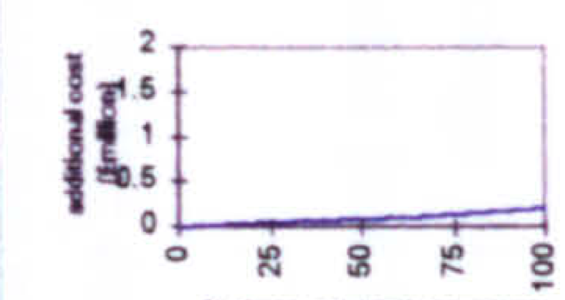
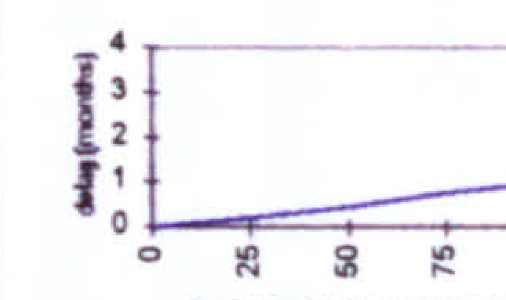
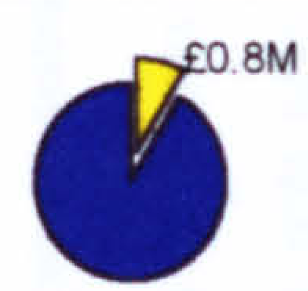
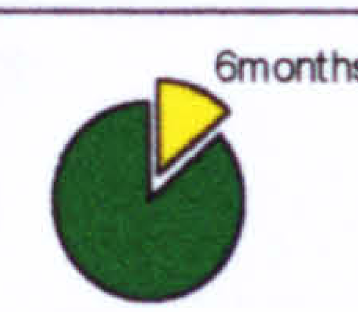
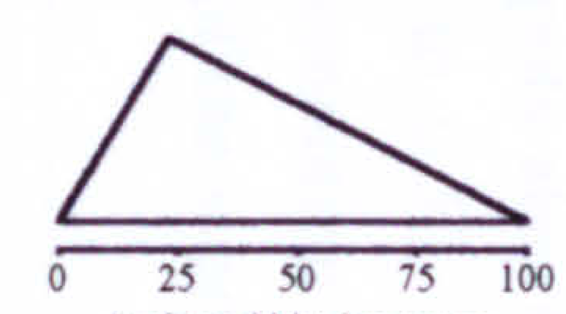
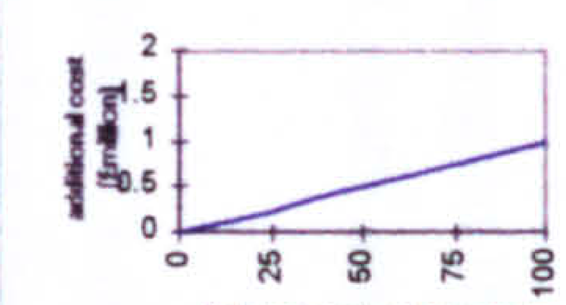
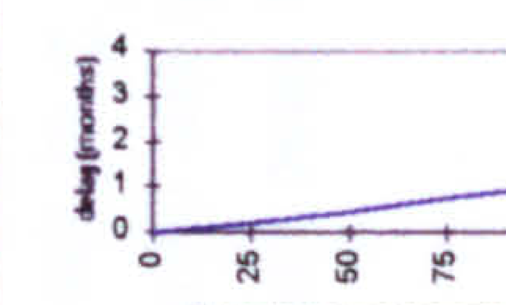
RISK NUMBER & NAME	RISK OWNER	ACTIVITY BASE COST	ACTIVITY BASE DURATION	RISK LEVEL OCCURRENCE PROBABILITY DISTRIBUTION	RISK LEVEL – ADDITIONAL COST RELATIONSHIP	RISK LEVEL – DELAY RELATIONSHIP
2.4.1 hard ground	Contractor					
2.4.2 water ingress	Contractor					
2.4.3 machine failure	Contractor					
2.5.2 grout required	Contractor					

Table 6.4 The revised inputs for FP

Once the new estimates were inputted for FP the model calculated, and subsequently displayed, probability distributions of:

- *The contractor's costs.* This includes the base cost of all the activities in work package 2 and the cost of the risks which are owned by the contractor. Since FP allocates all the risks in work package 2 to the contractor this distribution is effectively a distribution of the cost of the work involved in work package 2.
- *The client's costs (for work package 2).* Owing to the inputs made for FP, the client costs for work package 2 includes just the costs associated with the tender process activity.

Figure 6.11 shows the distributions of the contractor's costs calculated from the original and revised inputs for FP. The revised inputs reduce the mean value of the contractor's costs from £11.6M to £10.9M. The revised inputs also reduce the standard deviation of the contractor's costs distribution from 1.09 to 0.50. Therefore it is evident that the additional cost and time expended in implementing the risk-reducing measures is justified by the potential reduction in the cost of the work.

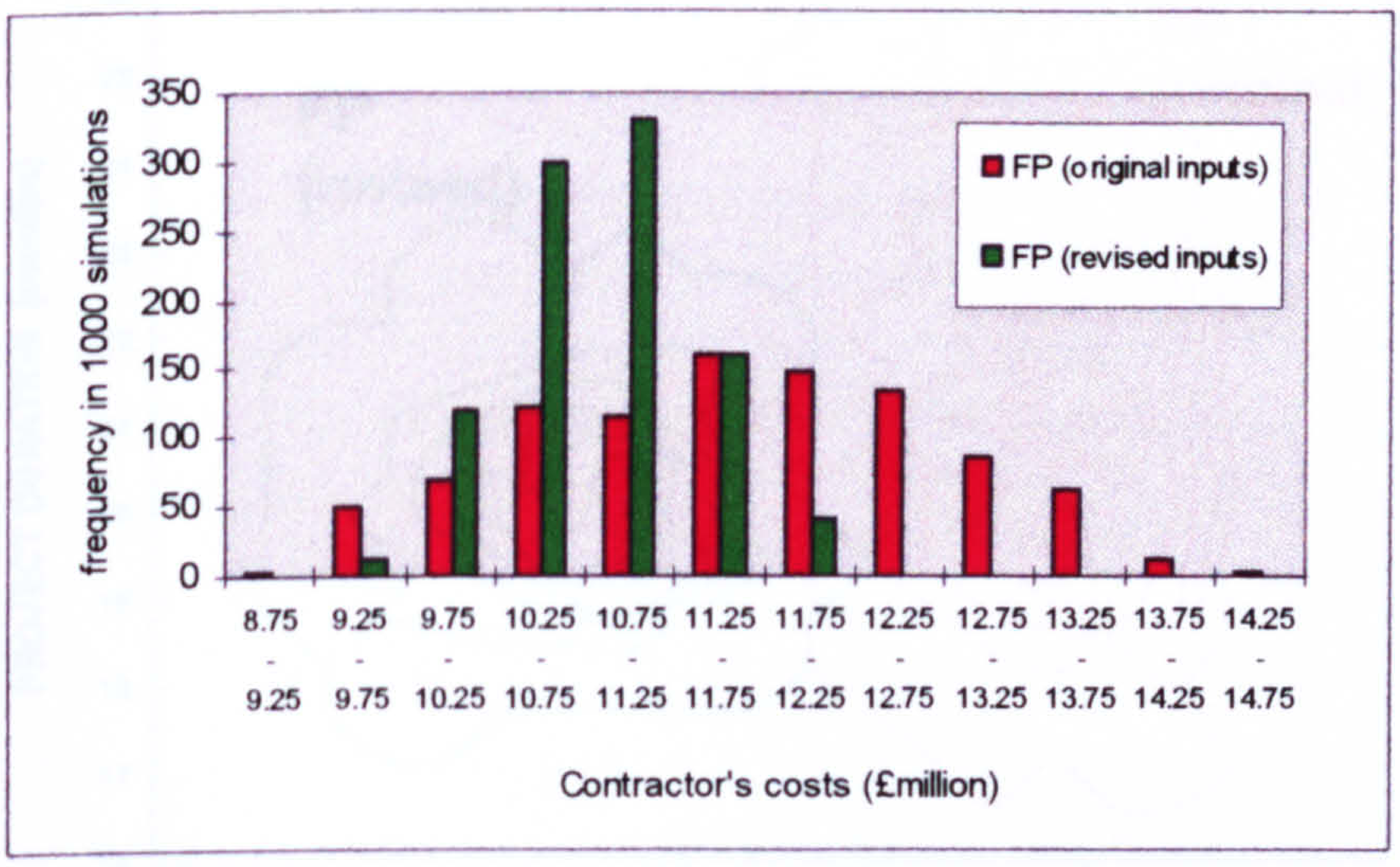


Figure 6.11 The contractor's costs under FP for both the original and revised inputs

Given the results in Figure 6.11 it appears that the contractor does not require a risk premium that is as large as that included in the fixed price bids estimated for FP in the preliminary analysis. Furthermore, since the risk-reducing measures decrease the uncertainty surrounding the cost of the work the estimated distribution of tender bids may cover a smaller range of values. However, it was decided to employ the same bidding strategy as that used in the preliminary analysis of FP (i.e. the same levels of mark-up which are specified as percentages of the most likely cost of the work were used).

Fixed price bidding strategy used for FP (based upon the revised inputs for FP)

Most likely cost of the work (derived from the results shown in Figure 6.11) = £10.9M

The distribution of tender bids are estimated as different levels of mark-up added to the most likely cost of the work. These levels of mark-up are specified as percentages of the cost of the work. The mark-up is intended to include an adequate risk premium and a margin of profit.

Minimum fixed price bid	= 1.12 x 10.9 = £12.2M	(i.e. 12% mark-up)
Most likely fixed price bid	= 1.20 x 10.9 = £13.1M	(i.e. 20% mark-up)
Most likely fixed price bid	= 1.22 x 10.9 = £13.3M	(i.e. 22% mark-up)

Figure 6.12 shows the project price and duration results calculated from both the revised and the original inputs for FP. Figure 6.13 displays the contractor's financial outcome under FP calculated from the original inputs and from the revised inputs.

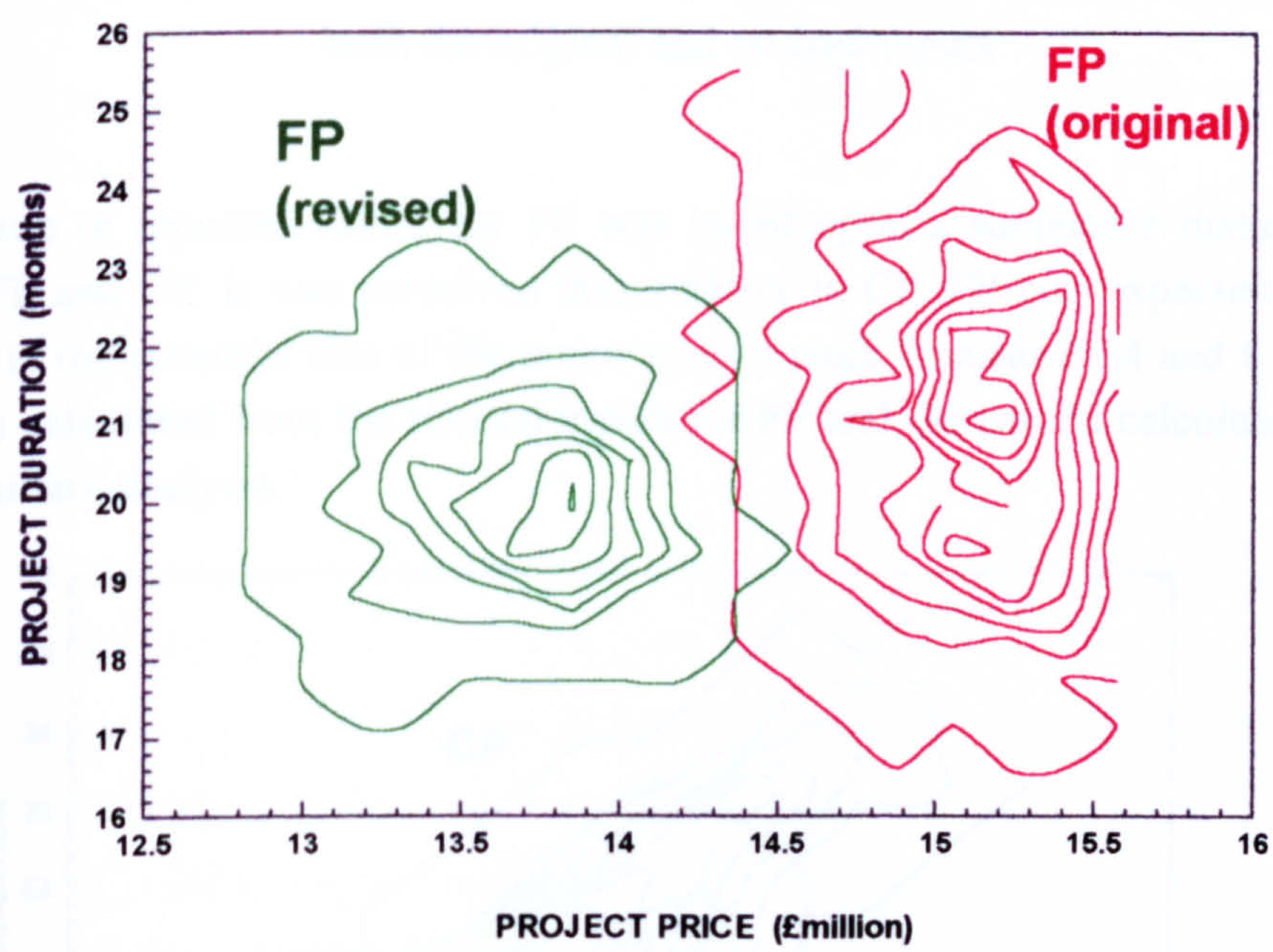


Figure 6.12 Comparison of the price and duration results for FP calculated from both the original and revised inputs

It appears that effective management of the risks will be to the advantage of the contractor as well as the client. Figure 6.13 illustrates that implementing the risk-reducing measures is likely to provide a more secure profit margin for the contractor. The mean financial outcome of the contractor calculated from the original and revised inputs for FP are £2.68M and £1.98M, respectively. The original inputs for FP presented the contractor with a 0.01 probability of making a financial loss, but a 0.93

probability of making a profit which exceeds £1M. The revised inputs for FP have eliminated the possibility of the contractor making a loss (the minimum outcome was calculated at £0.19M). In addition the probability that the contractor will make a profit that exceeds £1M has increased slightly to 0.96.

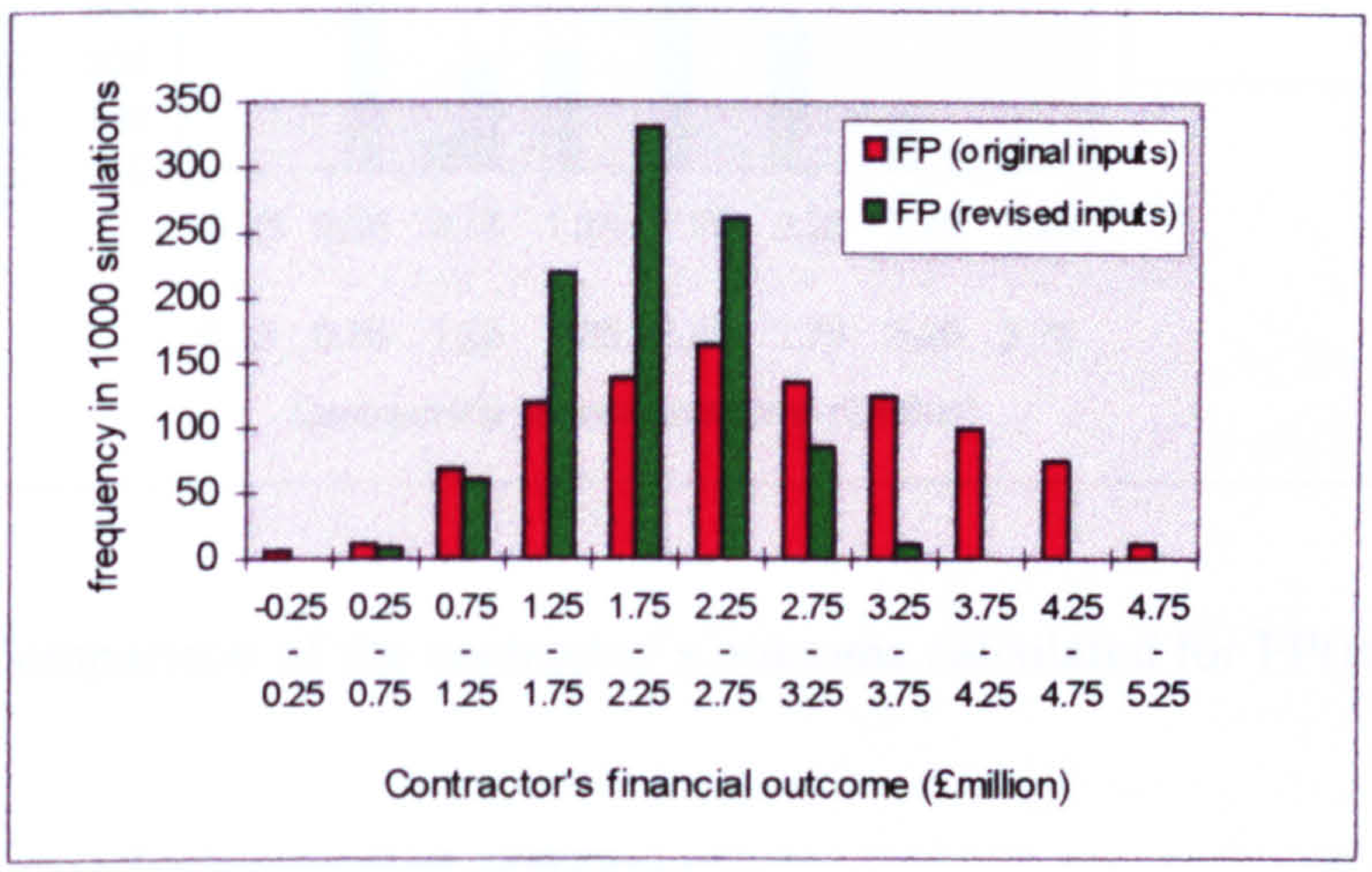


Figure 6.13 Comparison of the contractor's financial outcome for FP calculated from both the original and revised inputs

The revision of inputted values for FP was based upon a subjective distinction made between FP and CP. It was perceived that, relative to CP, FP was expected to induce a reduction in the potential size of the major project risks. Figures 6.14 and 6.15 compare the results calculated from the revised inputs for FP and the results calculated for CP in the preliminary analysis.

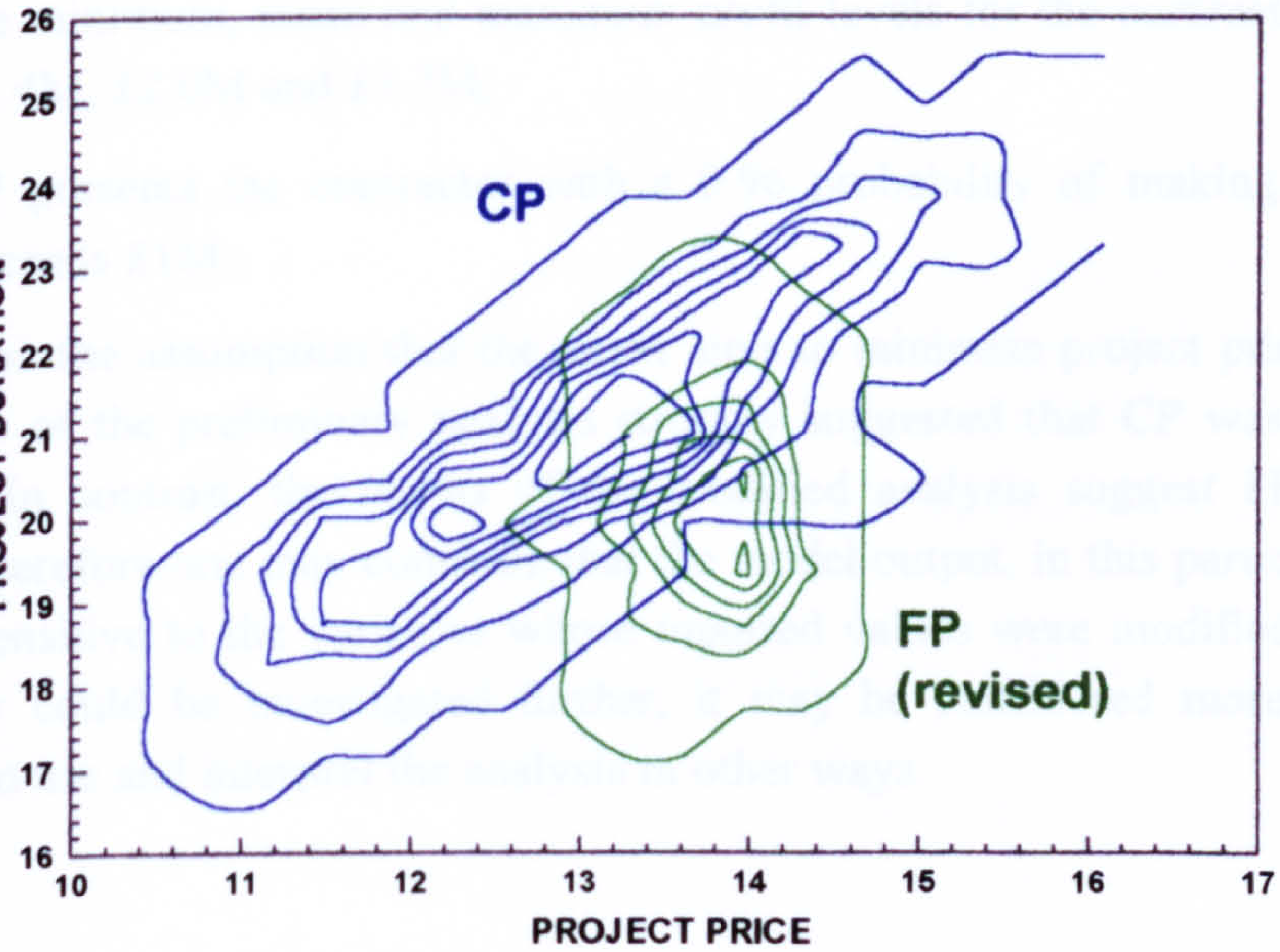


Figure 6.14 Comparison of the project price and duration results calculated for FP(revised) and CP

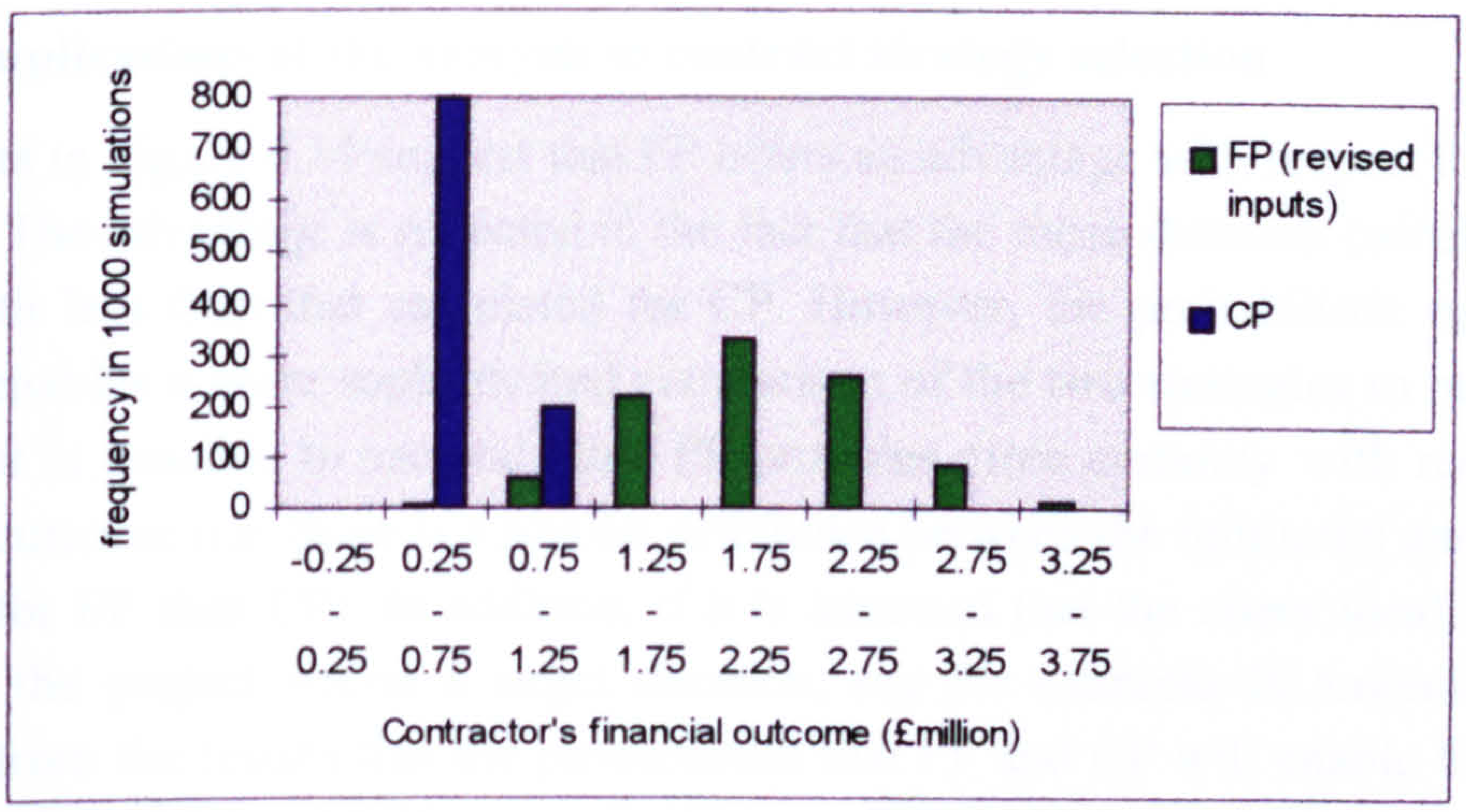


Figure 6.15 Comparison of the contractor's outcome calculated for FP(revised) and CP

The results may be interpreted as follows:

- the mean project price for FP and CP are £13.6M and £12.9M, respectively;
- there is a probability of 0.45 that CP will induce a lower project price than the minimum possible price for FP;
- there is a probability of 0.14 that CP will induce a higher project price than the maximum possible price for FP;
- there is a probability of 0.95 that the contractor's profit for CP will lie between £0.4M and £0.9M;
- the minimum, mean and maximum profit levels for the contractor under FP are £0.4M, £2.0M and £3.7M;
- FP presents the contractor with a 0.96 probability of making a profit which exceeds £1M.

Based upon the assumption that the client aims to minimise project price and duration, the results of the preliminary analysis strongly suggested that CP was a better option than FP. In contrast, the results of the modified analysis suggest FP is a plausible option. Therefore one may conclude that the model output, in this particular analysis, is notably sensitive to the variables whose inputted values were modified. Although this sensitivity could be investigated further, it may be considered more beneficial and efficient to use and interpret the analysis in other ways.

6.1.8 Implications of the analysis to contract strategy selection

The results in Figure 6.14 suggest that FP offers an advantage with respect to the project duration. The advantage is reflected in the fact that the mean duration calculated for FP is 1 month less than that calculated for CP. However, the probabilistic nature of the analysis enables a more sophisticated comparison of the two strategies to be made. For example it is possible to ascertain that FP provides more certainty with respect to the duration outcome (i.e. there is a smaller difference between the minimum and maximum duration for FP than CP). In addition, if it is assumed that the client ideally wishes to complete the project within a target duration, say for example 20.5months, one can interpret from the results that the probabilities that FP and CP will enable this target to be achieved are 0.80 and 0.45, respectively.

Figure 6.14 clearly illustrates that FP is expected to restrain the maximum project price to a lower level than CP. However, one could infer that this advantage is not too significant given the information that the probability that CP will induce a higher price than the maximum price calculated for FP is only 0.14. Furthermore, the appeal of CP with respect to project price is increased in light of the 0.45 probability that CP will induce a lower project price than the minimum price calculated for FP. The project price appeal of CP is even further reinforced if one reflects upon the assumptions behind the modified analysis. This is because the subjective distinction made between FP and CP effectively maximised the positive aspects of FP.

Owing to the evident price appeal of CP, one may claim that the fixed price tender bids estimated for FP were too high. A review of the contractor's financial outcome under FP (Figure 6.15) provides some justification for this claim. Figure 6.15 shows that the contractor's profit is expected to be substantially higher for FP than CP. Therefore one might conclude that the analysis should be modified in order to asses the impact of an alternative fixed price tender bidding strategy for FP.

The flexible structure of the model lends itself to iterative analyses. However, in some instances it can be more efficient and logical to manipulate previously calculated results using alternative analytical techniques. For example, Figure 6.16 illustrates a very basic probability tree which was used to approximate the project price distribution assuming:

1. there is a 0.6 probability that the major project risks will be managed to the extent represented in the modified analysis; and
2. there is a 0.4 probability that the major project risks will be managed to the extent represented in the preliminary analysis.

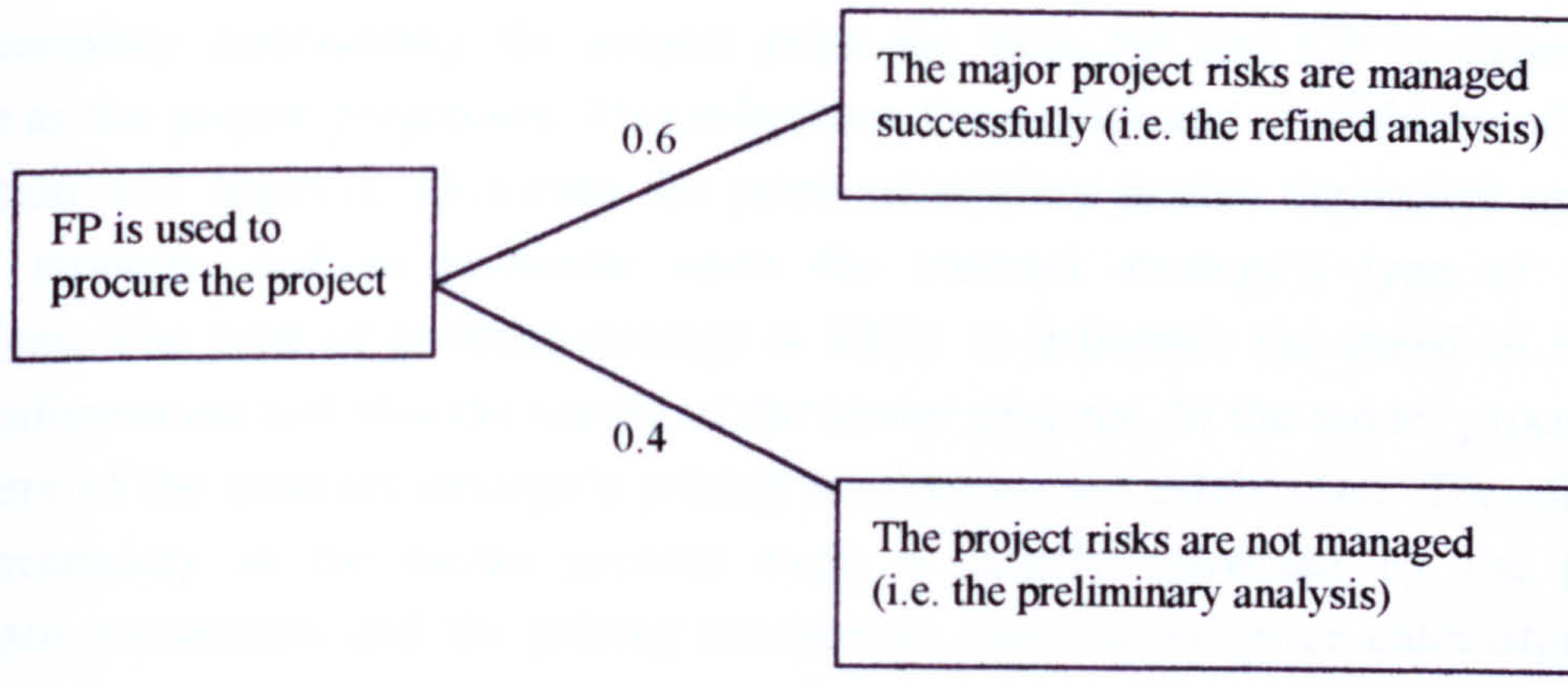


Figure 6.16 Probability tree indicating the likelihood that the major project risks will, and will not, be successfully managed if FP was used

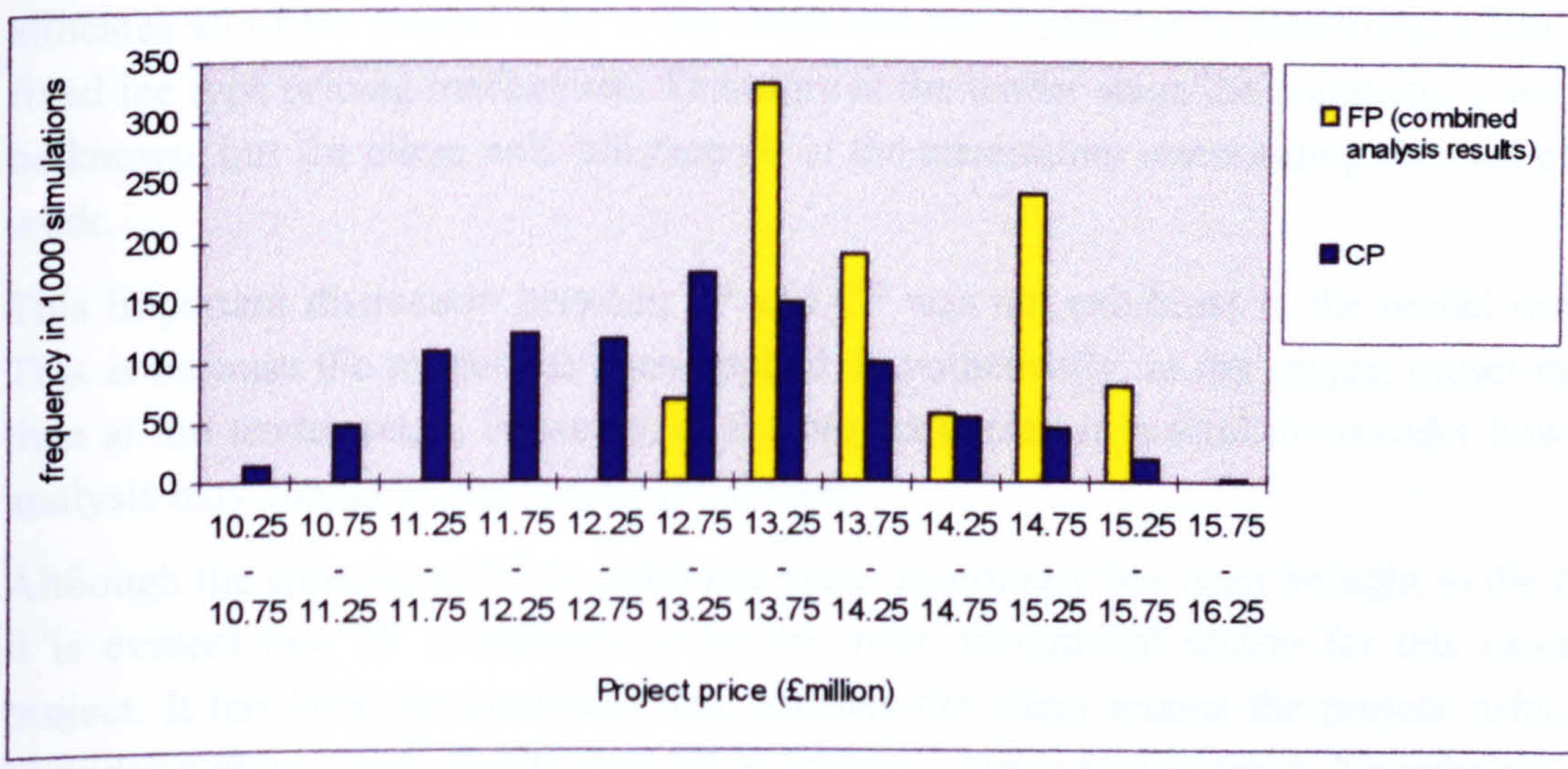


Figure 6.17 Comparison of the project price results calculated for CP with those calculated for FP (in both the preliminary and refined analysis)

Figure 6.17 shows the project price distribution for FP that results form the application of the probability tree in Figure 6.16. Figure 6.17 compares this distribution with the project price distribution for CP. This figure reiterates the greater opportunity offered by CP to minimise project price. It also provides a more accurate reflection of the price uncertainty which surrounds FP. However, it is very important to the decision process to recognise that this is the price uncertainty at the timing of the analysis (i.e. at the outset of the project).

The uncertainty surrounding the project price for both FP and CP is expected to decrease as the project progresses. This is because the quality and availability of project information will improve. However, the price uncertainty is also dependent upon the contract strategy, and in particular upon the contract strategy's type of pricing mechanism. The type of contract strategy is likely to influence the speed of flow of project information and also the timing of the tender process. At the tender process, the parameters of the contract strategy's pricing mechanism are established. Therefore the price uncertainty at the tender process stage is largely governed by the pricing mechanism parameters and the pricing mechanism formula for price calculation (see Table 5.6).

In this case, FP employs a fixed price type pricing mechanism and this fixed price is required to cover the cost of all of the work including its related risks. Therefore, from the client's perspective, the price uncertainty surrounding work package 2 will be eliminated at the tender stage. The price uncertainty for FP will simply reflect the cost uncertainty surrounding the client's project management activity. In contrast, CP allocates all of the project risks to the client and the contractor is paid using a cost plus fixed fee type pricing mechanism. Therefore at the tender stage the contractor's fee will be known, but the client will still face all of the uncertainty surrounding the cost of the work.

This important distinction between FP and CP was not exhibited in the model results. This is because the model has been applied, hypothetically, at the project outset rather than at the tender stage. However, at the project outset, it is vital to consider how the analysis may change as the project progresses.

Although the capacity of FP to minimise price uncertainty has been brought to the fore, it is evident that FP is unlikely to be the most economical option for this example project. It has been demonstrated that, because the client retains the project risks, CP provides a greater opportunity than FP to achieve a lower project price. Nonetheless, the modified analysis highlighted that both the mean and spread of the project price and duration could be significantly reduced if the major risks were successfully managed. This is independent of who owns the risks. It is suspected that CP is unable to induce the maximum possible reduction in the project risks because:

1. CP does not allocate the risks to the contractor which is assumed to be the party most able to control the risks; and
2. CP provides virtually no incentive to the contractor to minimise the project price which includes the cost of the risks.

In order to balance the advantages of FP with those of CP it would appear that the evaluation process may benefit from an analysis of contract strategies which share the project risks between the client and contractor. It could be decided that the most appropriate contract strategies to evaluate are those which are similar to FP and CP but which use a target cost type pricing mechanism. This pricing mechanism type essentially allocates the project risks to the client because the work is paid on a cost-reimbursable basis. However, a target cost is agreed at the tender stage and the overrun or underrun of the actual cost relative to the target cost is shared (not necessarily equally) between the client and contractor. Therefore, although the client retains the project risks, the contractor has an incentive to minimise costs.

Since this type of contract strategy places some responsibility onto the contractor, the target cost will include a premium to cover the contractor's share of the responsibility. As a consequence, if a target cost type pricing mechanism was used it is possible that the project price may cost the client more than if CP was used. Although this argument could continue discursively, it is suspected that application of the model will help to resolve it.

The preceding sections have presented one example way in which the model could be applied to the tunnel project. It has been demonstrated that the model-user/decision-maker has the flexibility to use the analysis (both inputs and outputs) in whatever way he/she considers appropriate.

In particular, this first example project has provided a clear demonstration of how to apply the model. It reports the model input steps for a single contract strategy (i.e. FP) in detail.

The model application to the tunnel project was relatively straightforward. In the preliminary analysis, the estimates of cost and time values for the two contract strategy options were the same. The model was simply used to investigate the effect of the objective differences between the two options. These differences existed in the contract strategies' risk allocations and pricing mechanism types.

However, each construction project is subject to its own set of circumstances. These circumstances may be inherent of the project or imposed by project participants. Therefore, following the preliminary analysis, the inputs for FP and CP were re-assessed in order to ascertain whether it was appropriate to account for any case-specific factors.

Owing to the objective differences between FP and CP, it was decided to modify the preliminary analysis of the two contract strategies. The two modified inputs reflected the assumption that more effective risk control measures were likely to be implemented under FP compared to CP.

Section 2.2.4 reported that contract strategy selection is typically based upon subjective assumptions that make reference to relative advantages and disadvantages of contract strategy types. The second example model application in this chapter focuses more upon the model's capacity to enable subjective assumptions about contract strategies to be incorporated into the analysis.

6.2 Example project 2: factory and office building

In this example it is assumed that a medium-sized computer manufacturing company wishes to expand and provide premises at a second location. A three-storey building is required (7000m^2). The ground floor is planned to house machinery while the first and second floors are to provide office space. The green-field site is located on the outskirts of a town. Several surrounding sites have been developed in recent years.

The company's only construction experience was gained when its current premises were constructed 6 years earlier. The previous project was similar to the current project. The client used a contract strategy based upon the Traditional type organisational structure. Although the client considers the project was executed fairly successfully, the client has expressed a preference to complete the current project within a shorter period of time.

The client perceives that the sooner the building is in operation the better. However, the client is prepared to implement a contract strategy that may compromise the project's time performance providing it provides a sufficient guarantee that the price budget will not be exceeded. In other words, the client organisation has assigned priority to its price budget of £5.3M. Although project duration is of secondary importance, the client stipulated 120 weeks as the maximum permissible project duration.

The following sections show how the model might be applied to aid contract strategy selection for this project. Section 6.2.1 describes the starting point for this process.

6.2.1 Initial overview of contract strategy selection

The client organisation had been the client of a previous, similar project that was adjudged to have been executed fairly successfully. Therefore it appeared that the same contract strategy option used to procure the previous project ought to be considered for the current project. This option is referred to, hereafter, as the Trad option because it utilises a Traditional type organisational structure.

Although the client does not have any major objections to using the Trad option again, the client has expressed a preference to complete the project within a shorter time than the previous project. Therefore it was decided to evaluate a contract strategy option that utilises a Design-Build type organisational structure because this general type of arrangement facilitates fast-track construction. Other attributes which led to this choice of option to evaluate are reported in section 6.2.2.3.

The Design-Build type option is referred to, hereafter, as the D-B option. Outline descriptions of both the Trad and D-B contract strategy options are provided in Figure 6.18.

Trad option:

The client's principal adviser, appointed at the project sanction stage, undertakes the contract administration on behalf of the client throughout the project.

The client appoints an engineering consultants organisation to undertake the design work, including the conceptual design. The majority of risk relating to the conceptual design is borne by the client.

At completion of the design, selected contractors are invited to submit fixed price tender bids for the entire construction work, using a full bill of quantities. The successful tenderer is allocated the bulk of the risk related to the work covered by the contract, with the exception of risk related to ground work. The client retains this risk.

D-B option:

The client employs an organisation to act as the employer's agent throughout the project. The agent is also assigned principal responsibility to undertake the conceptual design, although the client assumes all of the risks until a design-build contractor is appointed after a two-stage tender process.

Once the client has established a project brief, selected contractors are invited to submit tender bids that include drawings and approximate cost estimates. A contractor is then singled out to work with the employer's agent and develop the conceptual design and negotiate a fixed price for the remaining design and entire construction work. Essentially, the design-build contractor is allocated all of the risk related to the work covered by the contract.

Figure 6.18 The contract strategy options initially evaluated

6.2.2 Model inputs for the Trad and D-B options

Figure 5.10 presented the steps involved in the specification of model inputs for a contract strategy.

6.2.2.1 Step 1: Specification of the general details regarding the contract strategy's work packages

Figure 6.19 shows the inputs used to represent the division of work imposed by the Trad contract strategy option. The first work package involves the design work which is to be undertaken by a party referred to as "Designer". The second work package equates to the contract for the construction work which is to be awarded to a party referred to as "Contractor". Figure 6.19 also shows that the model-user has opted to model the tender process and pricing mechanism type associated with the second work package. When prompted, the user specified a single stage tender process activity and described the activity as "competitive". When prompted with regards to the pricing mechanism type for work package 2, the user specified "fixed price".

Work package number	Contracting party label	Tender process	Pricing mechanism	Mngmt/Consultnts fee
1	Designer	☐	☐	☐
2	Contractor	☑	☑	☐

Figure 6.19 The general work package inputs for the Trad option

Figure 6.20 shows the inputs used to represent the division of work imposed by the D-B contract strategy option. The first work package involves the conceptual design which is to be undertaken by the employer's agent (named "Agent" in the model application). The second work package equates to the contract covering completion of design and construction. "Contractor" is the name given to the party to which this contract is awarded in the model application.

Owing to the fact that the design-build contractor is appointed using a two-stage tender process whilst the conceptual design is in progress, the design-build contractor will receive a fee for its conceptual design contribution. The inputs under the column headed 'Mgmt/Consultants fee' for work package 1 in Figure 6.20 indicates that the user has chosen to account for this fee explicitly in the analysis of the D-B option. When subsequently prompted, the user specified that the fee is to be a "lump sum".

Figure 6.20 also shows that the user has opted to model the tender process and pricing mechanism type associated with work package 2. When prompted, the user specified a two-stage tender process activity and described the activity as "two-stage". When prompted with regards to the pricing mechanism type for work package 2, the user specified "fixed price".

Work package number	Contracting party label	Tender process	Pricing mechanism	Mngmt/Consultnts fee
1	Agent	☐	☐	☑ Contractor
2	Contractor	☑	☑	☐

Figure 6.20 The general work package inputs for the D-B option

6.2.2.2 Step 2: Specification of the activities, risks and risk owners within each work package

Figures 6.21a and 6.21b list the activities chosen to be analysed within the first and second work package, respectively, for the Trad contract strategy option. The figures show that the user has opted to analyse the general risk related to each activity, as opposed to specific activity-risks. The owners of each risk, as designated by the Trad option, are also reported in the figures.

Work package 1			
Activity number	Activity name	General or Specific activity risk	General activity risk owner
1.1	conceptual design	G	client
1.2	detailed design	G	Designer

Figure 6.21a The activities, risks and owners of each risk specified for the Trad option's work package 1

Work package 2			
Activity number	Activity name	General or Specific activity risk	General activity risk owner
2.1	tender	G	client
2.2	foundation	G	client
2.3	frame	G	Contractor
2.4	service & finishes	G	Contractor

Figure 6.21b The activities, risks and owners of each risk specified for the Trad option's work package 2

Figures 6.22a and 6.22b list the activities chosen to be analysed within the first and second work package, respectively, for the D-B contract strategy option. The design and construction activities are the same as those specified for the Trad option. The second work package for the D-B option includes an additional tender activity to that of the Trad option because the D-B option uses a two-stage tender process.

Like the inputs for the Trad option, the user has opted to analyse the general risk related to each activity. However, the D-B inputs differ with respect to the owner of the foundation-risk. The D-B option allocates the foundation-risk to the design-build contractor while the Trad option allocates this risk to the client.

Work package 1			
Activity number	Activity name	General or Specific activity risk	General activity risk owner
1.1	concpetual design	G	client

Figure 6.22a The activities, risks and owners of each risk specified for the D-B option's work package 1

Work package 2			
Activity number	Activity name	General or Specific activity risk	General activity risk owner
2.1	tender	G	client
2.2	tender	G	client
2.3	detailed design	G	Contractor
2.4	foundation	G	Contractor
2.5	frame	G	Contractor
2.6	services & finishes	G	Contractor

Figure 6.22b The activities, risks and owners of each risk specified for the D-B option's work package 2

6.2.2.3 Step 3: Quantification of activities and risks

The model prompts the user to input cost and time estimates for the previously-specified activities and risks. A set of estimates is required for each contract strategy option. Therefore it is possible for the user to reflect the advantages and disadvantages which the user associates with each of the options in the appropriate estimates.

Table 6.5 presents a series of subjective assumptions that differentiate between the two contract strategies under evaluation in this model application. The blue subjective assumptions in Table 6.5 are perceived advantages of the D-B option relative to the Trad option. Meanwhile, the red subjective assumptions in Table 6.5 are perceived disadvantages of the D-B option relative to the Trad option. The first column in Table 6.5 reports which user-specified activity is expected to be affected by each subjective assumption.

Activities affected by each subj. assumption	Subjective assumptions that differentiate between the Trad and D-B contract strategy options Blue-face assumptions are advantages of the D-B option Red-face assumptions are advantages of the Trad option
Detailed design	Problems are expected with the statutory undertakers. The problems are expected to be minimised under the D-B option because it assigns overall responsibility to one party and a contractor is regarded as the most able party to assume this responsibility.
Detailed design	In contrast to the Trad option, the amount and quality of design drawings and production information will be rationalised under the D-B option.
Detailed design	Under the D-B option more effort is allotted, and more assistance is available, to establish a clear and comprehensive account of the client's requirements at the project outset (i.e. during conceptual design).
All activities (except conceptual design)	The particular client to this project is more suited to the inactive role imposed by the D-B option. Transaction costs (i.e. cost of administrative procedures across contractual interfaces) are likely to be negligible compared to those incurred under the Trad option.
All construction activities	In the event of any risk occurrence, the D-B option's single-point responsibility and simpler and more direct communication lines are expected to enable the appropriate action to be decided and expedited more quickly. Furthermore, being the party best able to control the risks, the contractor may also be able produce a design that minimises any disruption.
Foundation	Unlike the Trad option, the D-B option is expected to enable the foundations activity to be completed before winter commences (this is based upon the assumption that conceptual design begins at the commencement of the preceding winter (i.e. October))
Services and Finishes & Detailed design	Generally, a design-build contractor is likely to achieve better value for money with respect to the services and finishes work, even if the work is to be subcontracted. Furthermore, a more integrated design will ensure that this activity is completed faster under the D-B option despite the greater probability of problems occurring during fast track construction.
All construction activities	Under the Trad option the design is completed before contractors are invited to submit fixed price tender bids. In contrast, the D-B option requires a fixed price to be established at the conceptual design stage, when the price is subject to more uncertainty. Therefore, under the D-B option, a fixed price bid is expected to be based upon higher, more conservative estimates of the risk costs than the more accurate estimates used to establish a fixed price bid for the Trad option. The potential cost of any risks is also likely to be inflated because the construction market is fairly buoyant. Given that the D-B option exposes the contractor to more cost uncertainty than the Trad option, the risk costs associated with D-B option are expected to be most inflated by this factor.
All construction activities	An additional amount to the base cost is expected to be incurred under the D-B option because this option facilitates fast-track construction. Fast-track construction is expected to demand a more intense working schedule (e.g. 7 day working weeks). The additional cost and delay values associated with each activity's risk are also expected to increase owing to the greater possibility of problems arising.
Foundation	The D-B option allocates the entire foundation-risk to the contractor whereas the client retains this risk under the Trad option. Given that the more serious consequences of this risk are uncontrollable, the design-build contractor is likely to have a more pessimistic view of this risk's potential cost (i.e. estimate a higher level of additional cost values).
Conceptual design	The client used the Trad option on its only other previous project which was similar to the current project. Therefore the client is more familiar with the contractual-governed procedures, particularly at the project outset.
Conceptual design	In contrast to the Trad option, the D-B option places more pressure upon the client to specify and finalise the project requirements at the project outset. Therefore more cost and time is likely to be expended in order to establish the client's brief, particularly since the client has very limited construction experience.

Table 6.5 An example set of subjective assumptions that differentiate between the Trad and D-B options

The subjective distinctions made between the two contract strategy options were incorporated into the estimates of each option's cost and time elements. Each option's set of estimates are presented in Table 6.6. Beforehand, however, Figure 6.23 provides an example of how the cost and time estimates for an individual activity (in this case the foundation activity) may be progressively refined to incorporate a variety of contrasting subjective assumptions about the contract strategy options' potential impacts upon the activity.

Figure 6.23 shows the refinement of the estimates in five stages. The assumptions that are reflected in the estimates at each of the five stages are outlined below.

<u>Stage 1</u>

The building's foundations are expected to present some difficulties (e.g. piling may be required because of reports of subsidence in the area local to the site). Consequently, it is perceived that an application of practical construction experience during the design stage is likely to improve the management and execution of the foundation activity, including any risk events should they arise. Unlike the arrangement under the Trad option, the contractor at least manages the design and may also undertake the design under the D-B option. Therefore the values of the cost and time elements associated with the foundation activity are expected to be less if the D-B option, rather than the Trad option, is used to procure the project.

In addition, it is perceived that the design-build contractor has more incentive to apply its practical experience, particularly in the event of risk occurrence, because the D-B option allocates the foundation-risk to the contractor whereas the Trad option allocates this risk to the client. The D-B option is also likely to generate less disruption in the event of risk occurrence because this option assigns overall, single-point responsibility to the design-build contractor. Therefore the lines of communication between the decision-makers and the parties responsible for implementing the decisions are simpler and more direct.

The initial estimates of all the foundation activity's cost and time elements for the Trad and D-B options that reflect these assumptions are shown in the column headed 'Stage 1' in Figure 6.23.

<u>Stage 2</u>

The D-B option enables an earlier start on site than the Trad option (see schedule estimates in section 6.2.2.5). As a result, under the Trad option, the foundation activity is expected to extend into winter whilst the D-B option is most likely to enable the activity to be completed before winter commences. Therefore the initial estimates of all the foundation activity's cost and time elements for the Trad option were modified to account for this probable event (see Stage 2 in Figure 6.23).

The base cost and duration estimates were increased by £50k and 3 weeks, respectively, to reflect the likelihood of a lower productivity rate when the weather is expected to become more inclement. The same reason justifies the increase in values estimated for the delays that may result in the event of foundation-risk occurrence. Meanwhile, only the additional cost values at the higher end of the risk level scale were increased to account for the perception that the more serious consequences of the foundation-risk would particularly escalate if they coincided with exceptionally adverse weather conditions.

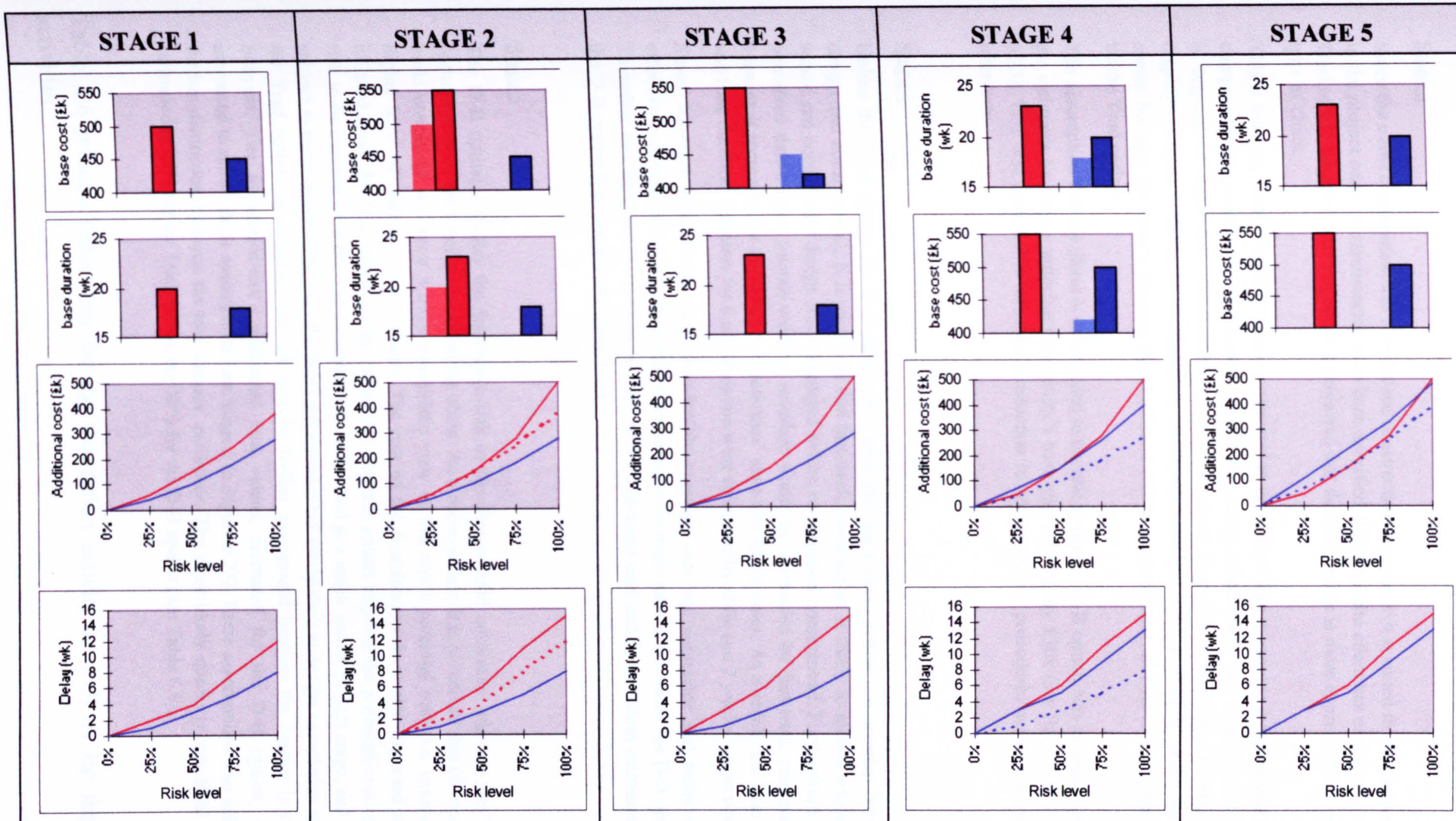


Figure 6.23 Refinement of the foundation activity estimates

Trad option   D-B option

[dotted lines and lighter shaded histogram bars show the estimate before refinement]

Stage 3

Since the client organisation has very limited construction experience it is suited to an inactive role in the project once its requirements have been specified. Although the client has experience of the Trad option on a previous project, it is perceived that the D-B option is more appropriate given the type of client.

This is because, firstly, the D-B option is expected to assist the client to provide a clearer and more comprehensive specification of requirements at a very early project stage, and secondly, the client is negated of significant responsibility once the contract is awarded, providing a competent employer's agent is appointed. Furthermore, the client's oversight is not as essential under the D-B option because this option allocates the foundation-risk to the contractor, not the client as imposed by the Trad option.

The assumption that the client is more suited to the role under the D-B option was accounted for in the estimates by simply reducing the activity's base cost estimate by £30k (see Stage 3 in Figure 6.23). This was intended to simulate a reduction in administrative procedures across contractual interfaces.

Stage 4

Unlike the Trad option, the D-B option facilitates fast-track construction (i.e. overlap between design and construction). It is perceived that fast-track construction is likely to induce errors that would not occur if the design was completed before construction commenced. Furthermore, it is perceived that a more intense working schedule would be demanded by fast-track construction because it increases the importance of activities' start and finish times. As a result, the base cost and base duration estimates for the D-B option were increased by £80k and 2 weeks, respectively.

Since fast-track construction puts considerable pressure onto the contractor and relies upon effective communication, any disruption is expected to be more substantial under the D-B option. Therefore this assumption led to an increase in the additional cost and delay values estimated for the D-B option (see Stage 4 in Figure 6.23).

Stage 5

The D-B option allocates the foundation-risk to the design-build contractor whereas the Trad option allocates the foundation-risk to the client. As a consequence, it is perceived that the design-build contractor will have a more pessimistic view of this risk's potential cost (i.e. estimate a higher level of additional cost values). The cost of the foundation-risk is also expected to be inflated under the D-B option owing to the fact that this option requires the potential cost of the risk to be covered by a fixed price tender bid established at a much earlier project stage, and thus subject to more uncertainty, than the fixed price tender bid established at design completion under the Trad option. In addition, the risk may be further over-priced because the market is fairly buoyant. The foundation-risk's additional cost values, estimated for the D-B option, were increased to reflect these assumptions (see Stage 5 in Figure 6.23). These assumptions also led to a further distinction between the two options' estimates. The most likely quarterly risk level was estimated at 25% for the Trad option, but 50% for the D-B option (see Table 6.6).

Table 6.6 presents input data for the foundation activity as well as for the other activities.

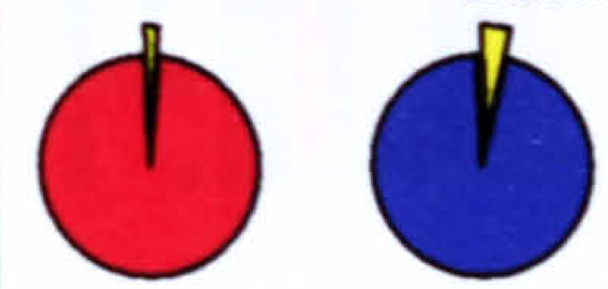
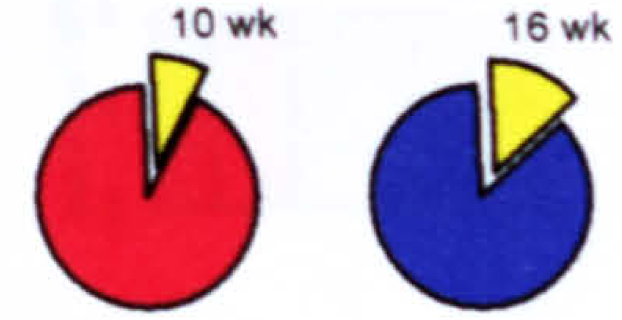
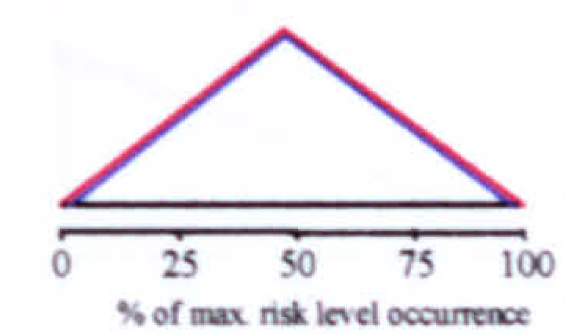
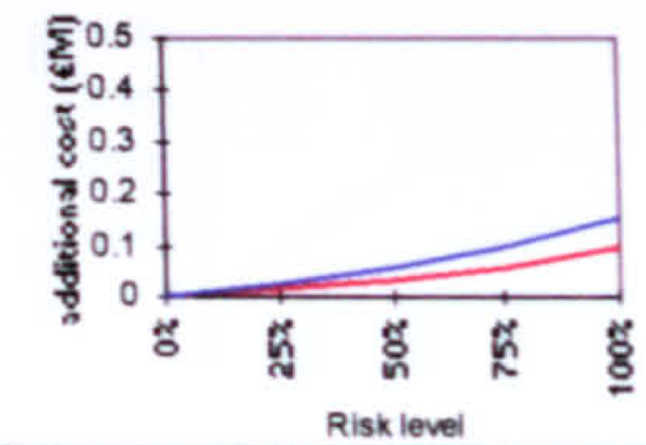
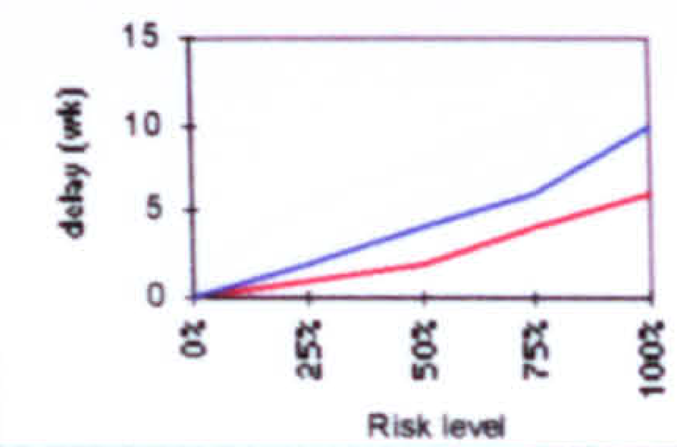
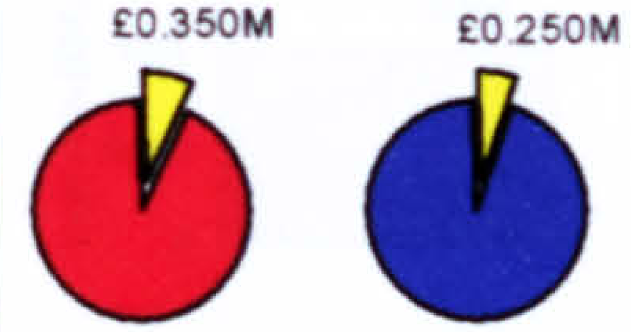
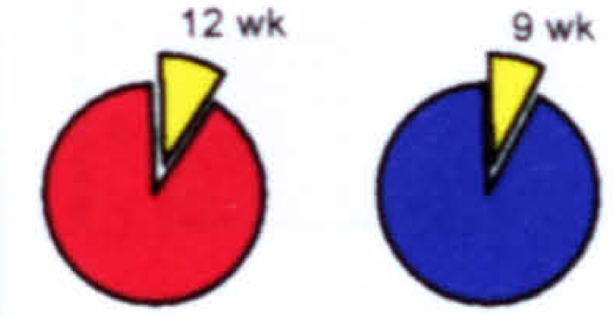
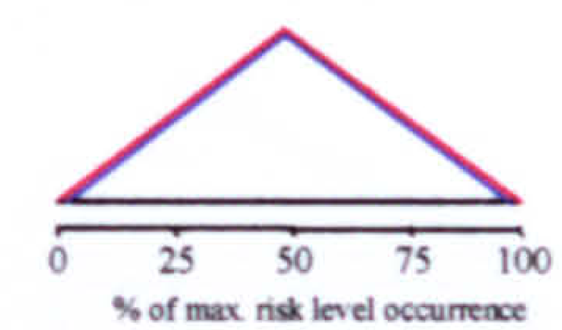
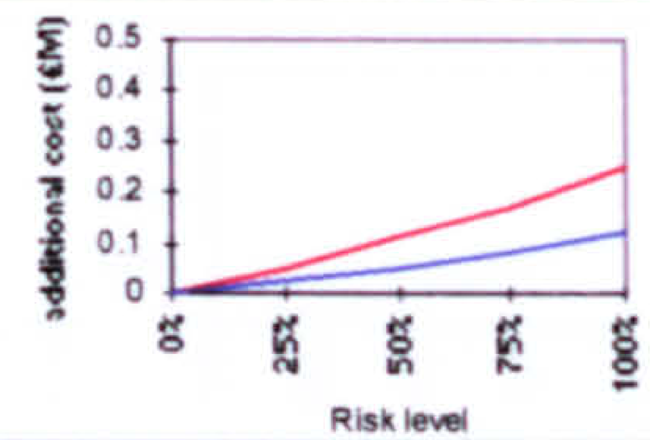
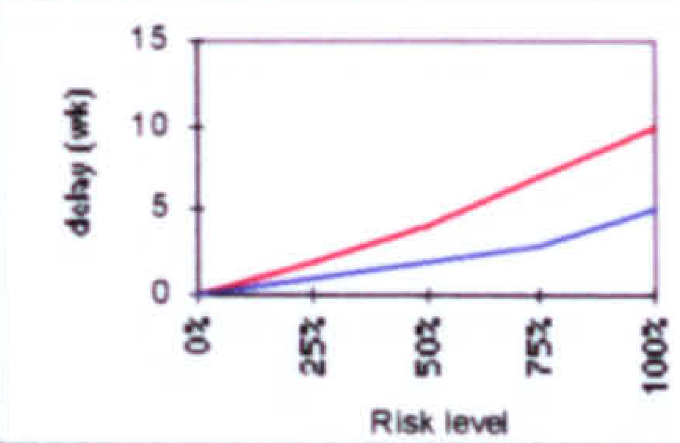
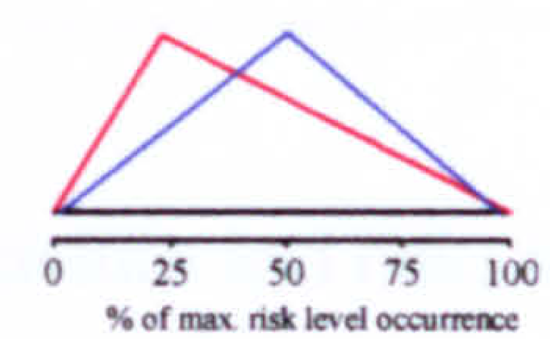
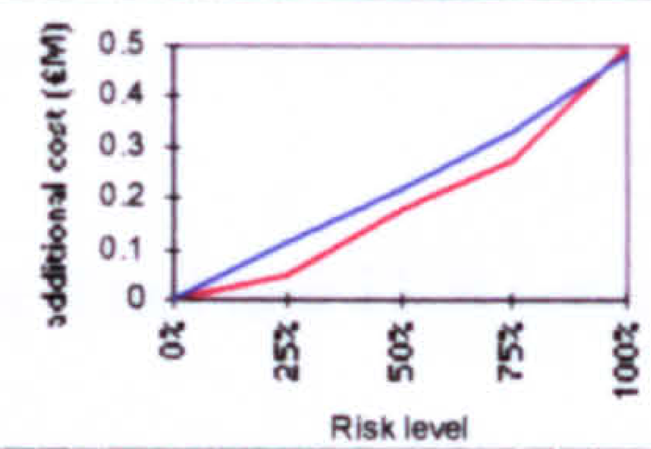
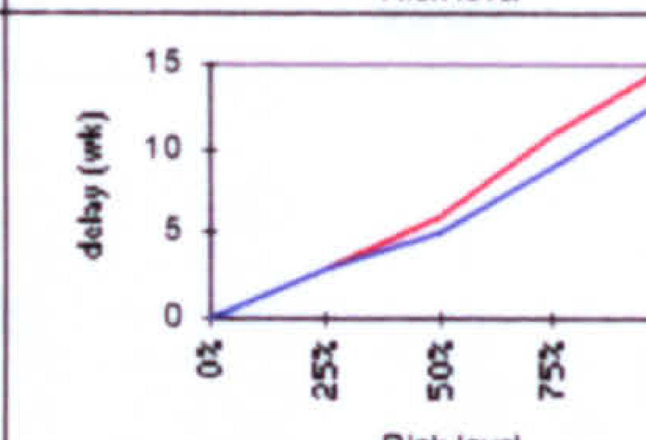
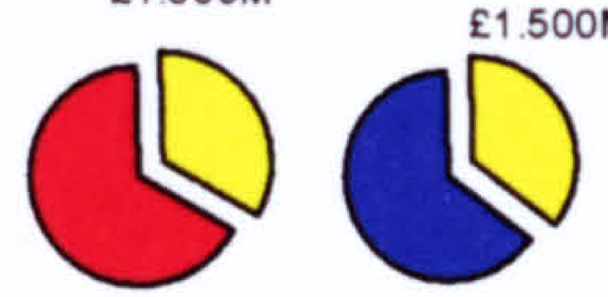
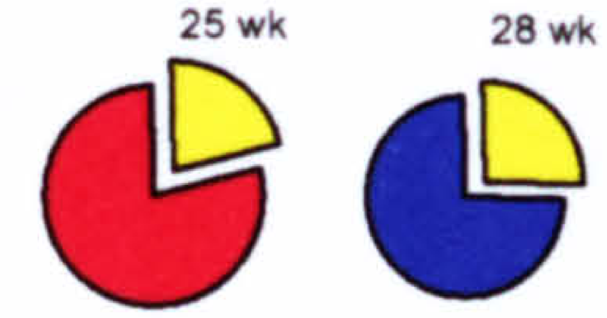
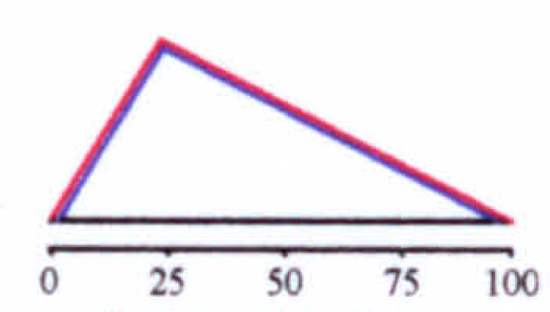
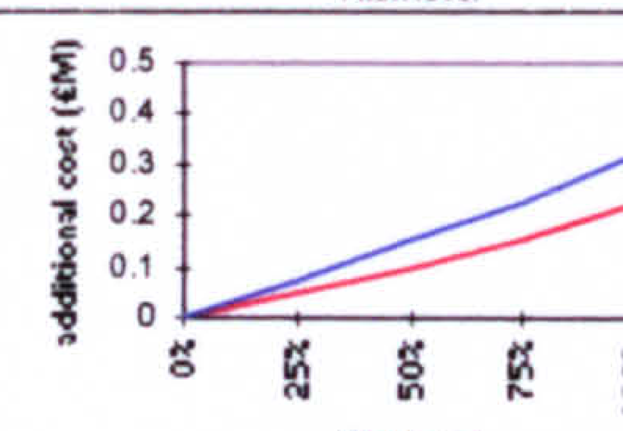
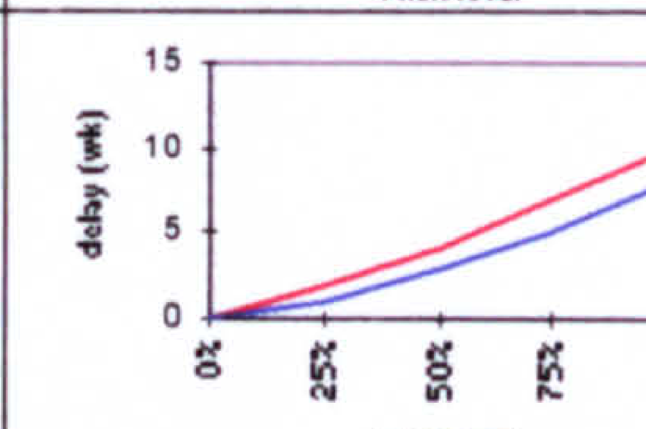
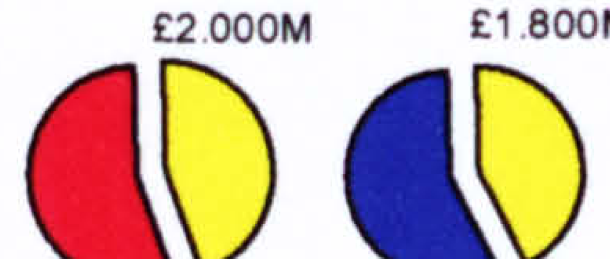
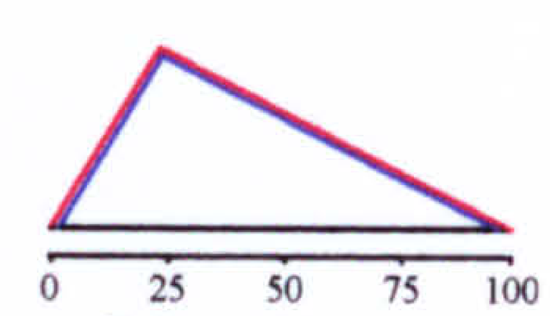
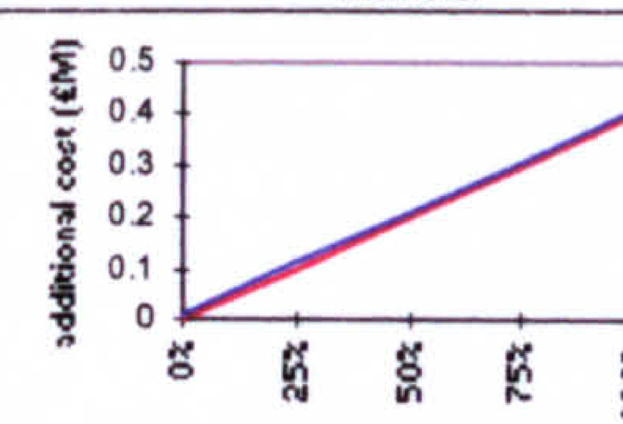
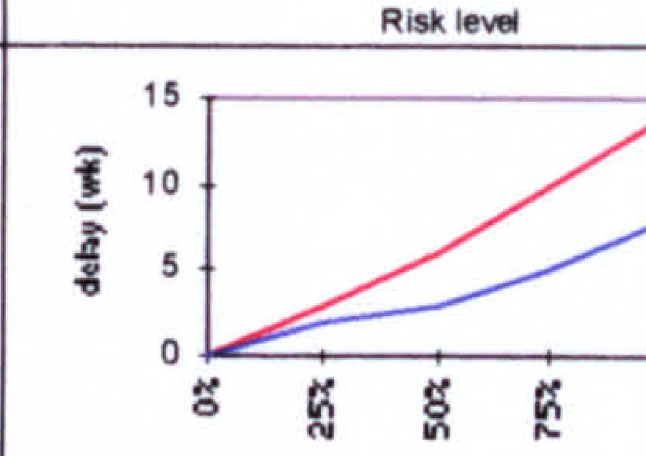
ACTIVITY NAME	RISK TYPE	ACTIVITY BASE COST	ACTIVITY BASE DURATION	RISK LEVEL OCCURRENCE PROABABILITY DISTRIBUTION	RISK LEVEL – ADDITIONAL COST RELATIONSHIP	RISK LEVEL – DELAY RELATIONSHIP
Conceptual design	General	£0.100M £0.200M 	10 wk 16 wk 			
Detailed design	General	£0.350M £0.250M 	12 wk 9 wk 			
Foundations	General	£0.550M £0.500M 	23 wk 20 wk 			
Frame	General	£1.500M £1.500M 	25 wk 28 wk 			
Services and Finishes	General	£2.000M £1.800M 	38 wk 30 wk 			

Table 6.6 Quantification of the activities and risks for the Trad and D-B options *(continued overleaf)*

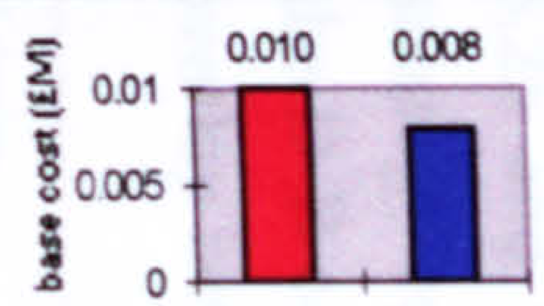
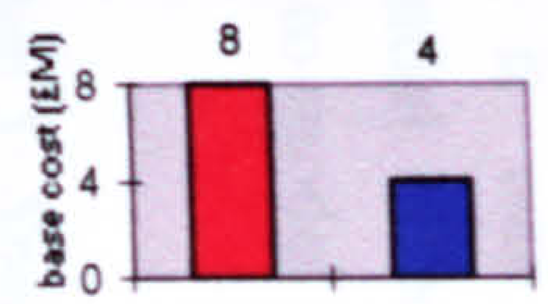
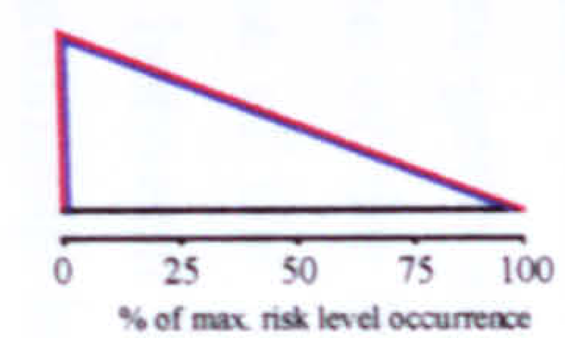
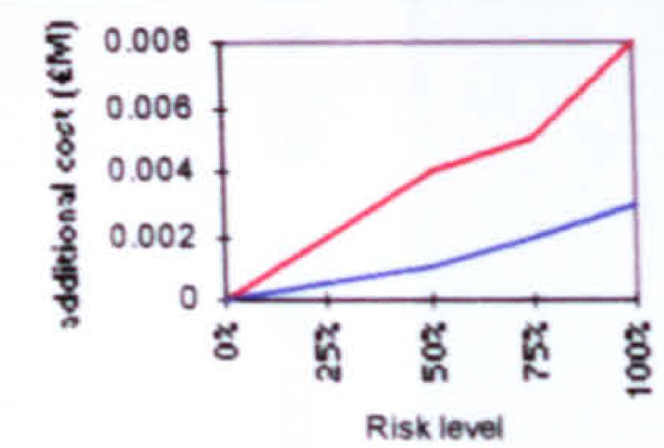
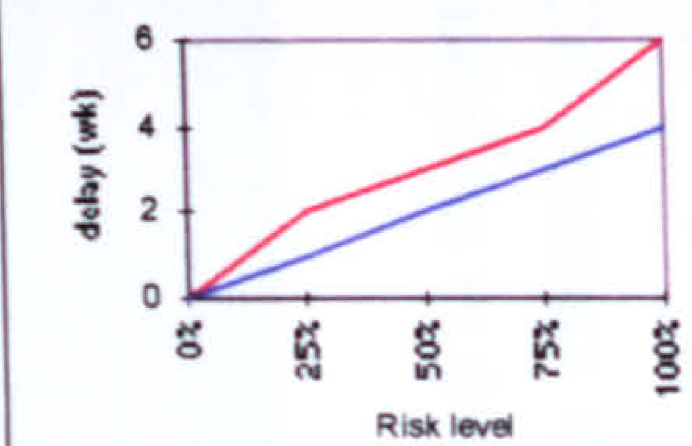
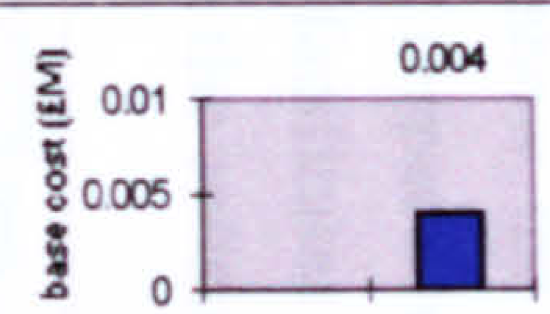
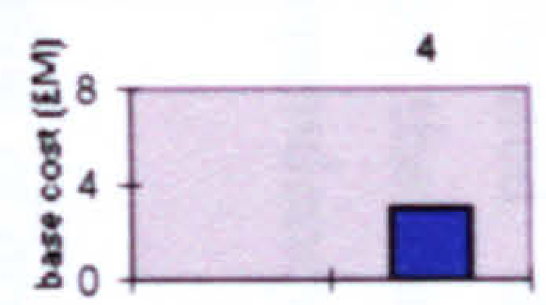
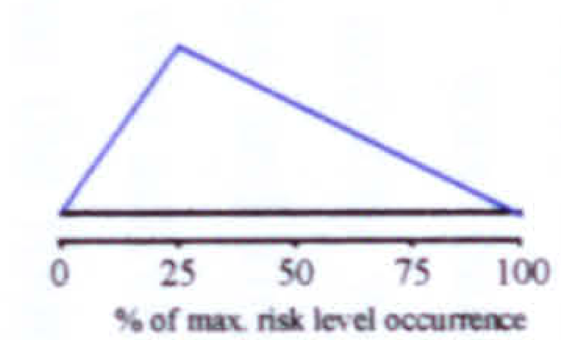
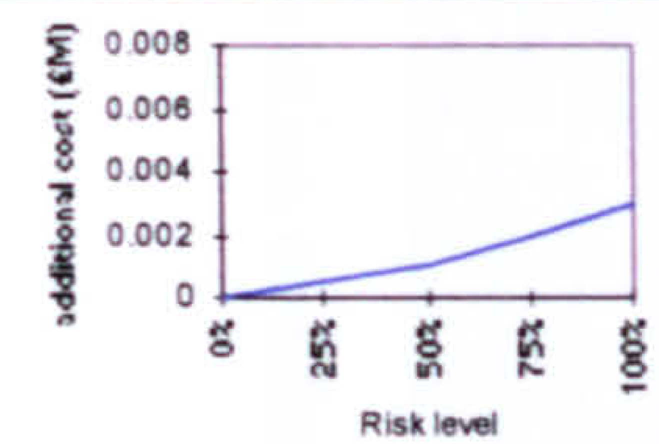
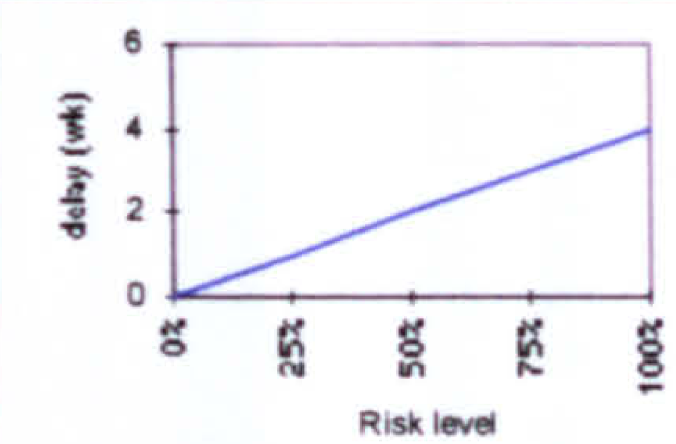
ACTIVITY NAME	RISK TYPE	ACTIVITY BASE COST	ACTIVITY BASE DURATION	RISK LEVEL OCCURRENCE PROABABILITY DISTRIBUTION	RISK LEVEL – ADDITIONAL COST RELATIONSHIP	RISK LEVEL – DELAY RELATIONSHIP
Tender process	General					
Tender process (second stage)	General					

Table 6.6 *(continued)* Quantification of the tender activities and risks for the Trad and D-B options

6.2.2.4 Step 4: Specification of correlation between risks

Figure 6.24 presents the correlation coefficients specified to model the dependencies between the risks in the model applications for both the Trad and D-B options.

Activity Name	Risk Name	Risk no.	1.1.0	1.2.0	2.1.0	2.2.0	2.3.0	2.4.0
conceptual design	general	1.1.0	1					
detailed design	general	1.2.0		1		0.5		
tender	general	2.1.0			1			
foundation	general	2.2.0		0.5		1	0.4	
frame	general	2.3.0				0.4	1	0.6
service & finishes	general	2.4.0					0.6	1

Figure 6.24 The correlation coefficient matrix inputted for both the Trad and D-B options

The specified coefficient value of 0.6 between the 'frame-general risk' and 'services and finishes-general risk' was based upon the perception that the cost and time performance of the frame activity was quite likely to be mirrored by the cost and time performance of the services and finishes activity. This is owing to the importance of integration between these two activities. The 0.5 correlation coefficient value specified for the relationship between the foundation and detailed design activities was intended to reflect the likelihood that substructure difficulties could require re-design work. In addition, it was anticipated that substructure performance could have some consequential effect upon the frame activity. Therefore a 0.4 coefficient value was specified to model this dependency relationship.

6.2.2.5 Step 5: Specification of project schedule

Figures 6.25 and 6.26 show the estimated project schedules for the Trad and D-B contract strategy option, respectively. The options' schedules differ with respect to the fact that the D-B option facilitates overlap of the design and construction stages as well as more overlap between the construction activities

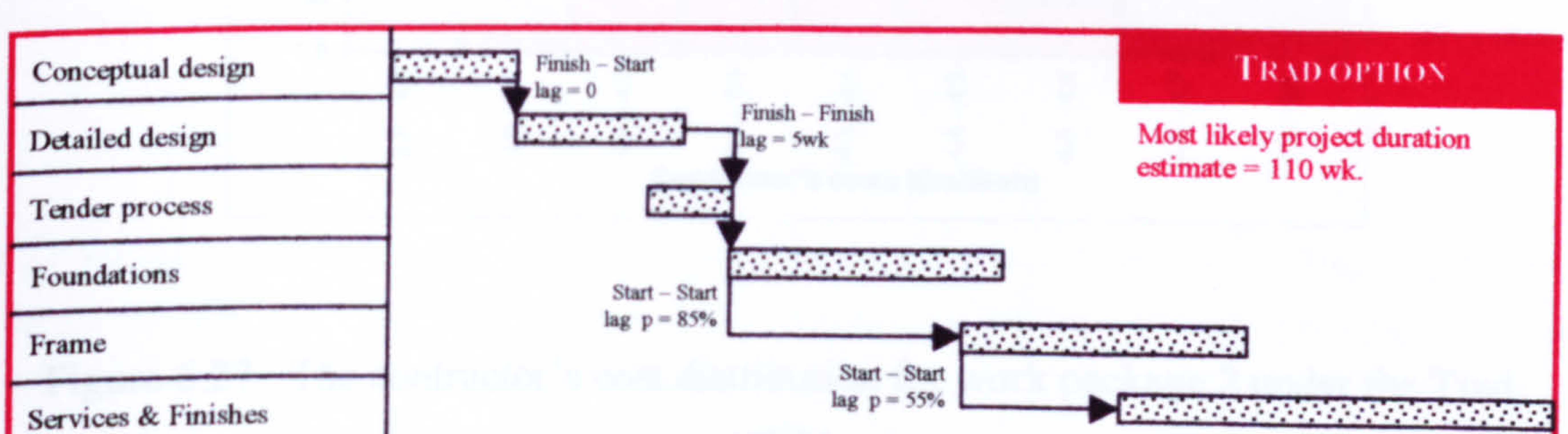


Figure 6.25 The project schedule inputted for the Trad option

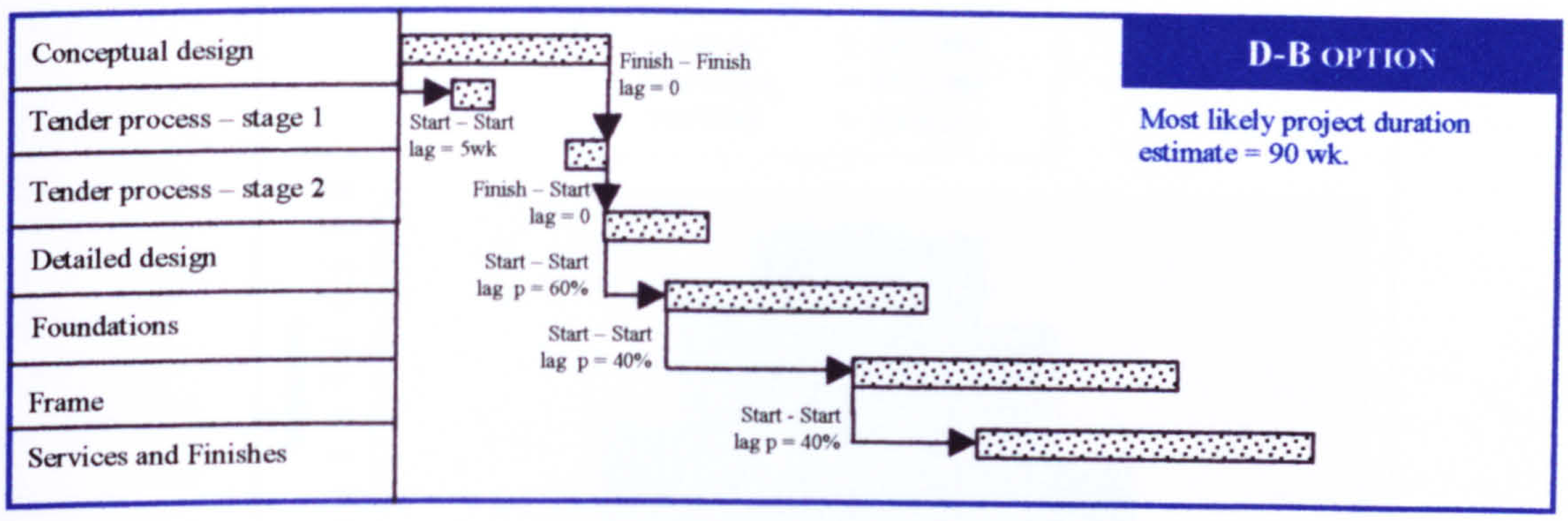


Figure 6.26 The project schedule inputted for the D-B option

6.2.2.6 Step 6: Specification of tender bids

The user opted to analyse the effect of a fixed price pricing mechanism type on the price of work package 2 for both the Trad and D-B contract strategy options. Therefore, for each option, the model calculates, and subsequently displays, the distribution of costs to be incurred by the party assigned responsibility for work package 2.

Figures 6.27 and 6.28 show the distributions calculated for the Trad and D-B options, respectively. These distributions were used to estimate a rational triangular probability distribution of fixed price tender bids for both contract strategy options.

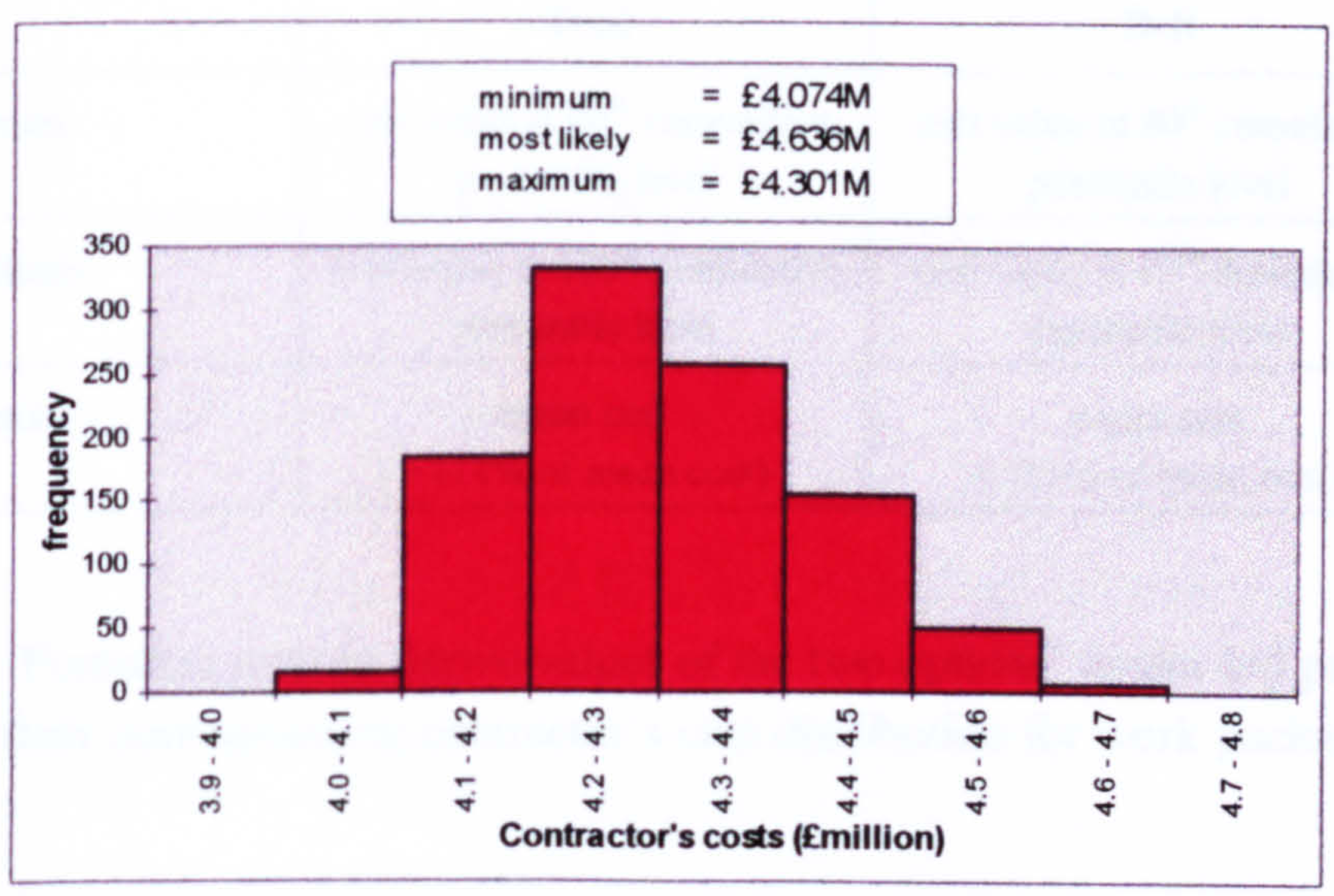


Figure 6.27 The contractor's cost distribution for work package 2 under the Trad option

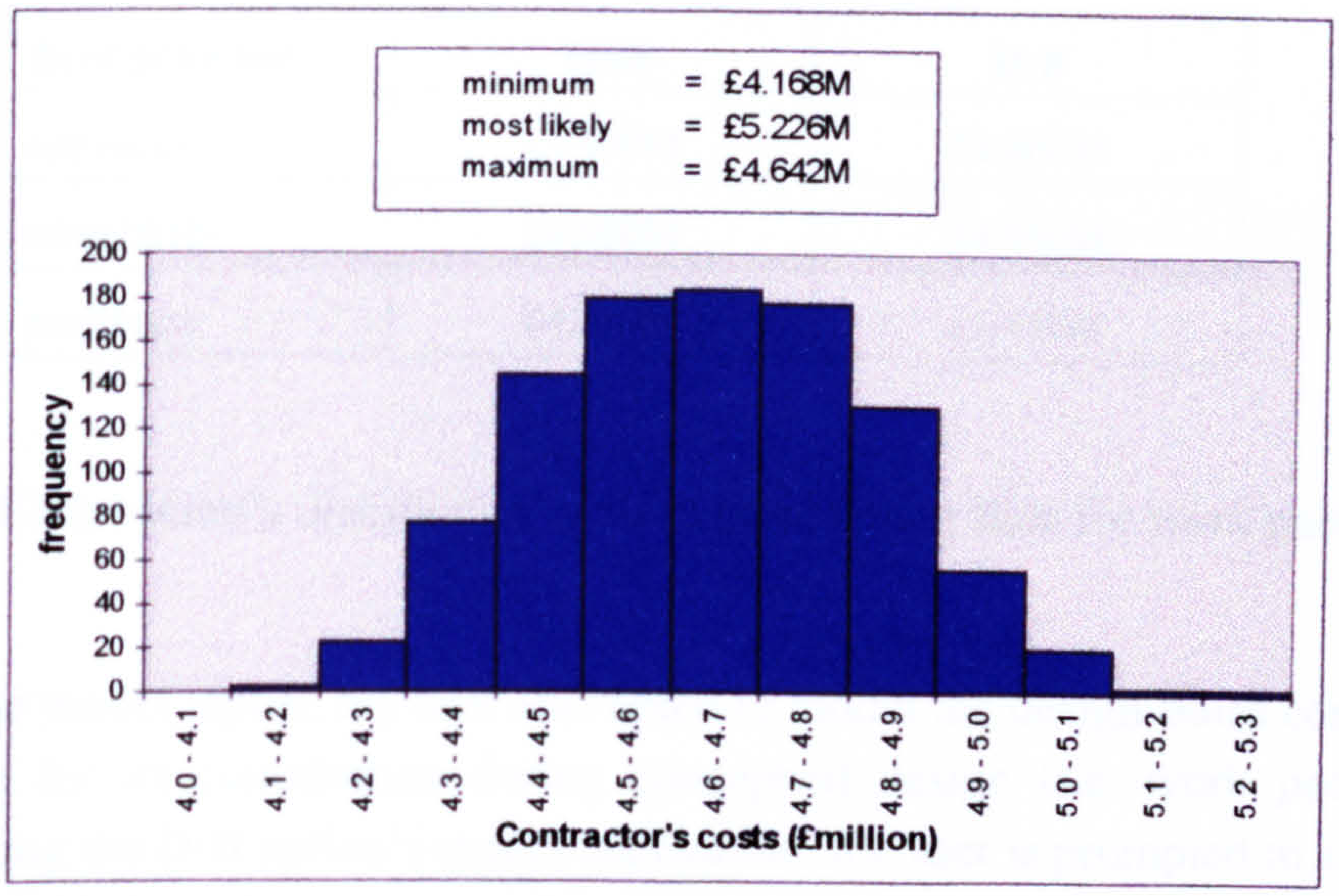


Figure 6.28 The contractor's cost distribution for work package 2 under the D-B option

Table 6.7 reports the formulae used to derive the minimum, most likely and maximum values of each option's triangular distribution of fixed price tender bids. It was decided to base the Trad option's most likely value on a higher cumulative percentile level because the distribution of contractor's costs, under the Trad option, covered a much smaller range of values than the distribution of the design-build contractor's costs.

	Trad	D-B
minimum	cost value at 80th cumulative percentile level	cost value at 80th cumulative percentile level
most likely	cost value at 100th cumulative percentile level	cost value at 95th cumulative percentile level
maximum	mean cost + (11% of mean cost)	mean cost + (11% of mean cost)

Table 6.7 Formulae used to derive values of the two options' tender bid parameters from their corresponding contractor's cost distribution for work package 2

The values of the minimum, most likely and maximum fixed price bids inputted into the model for the Trad and D-B options are presented in Table 6.8. It is important to note that the fixed price bids for the D-B option are intended to cover the contractor's cost of the detailed design and the construction whilst the fixed price bids for the Trad option are intended to cover just the construction costs

fixed price bid	Trad	D-B
minimum	£4.400M	£4.800M
most likely	£4.600M	£4.950M
maximum	£4.750M	£5.150M

Table 6.8 Each option's distribution of fixed price tender bids for work package 2

At step 1 of the model inputs, the user also opted to model the design-build contractor's lump sum fee for its contribution during conceptual design (i.e. work package 1). Therefore, during the D-B option's model application, the user is prompted to estimate a minimum, most likely and maximum value of the lump sum fee amount. The estimated values are shown in Table 6.9.

	Design-build contractor's lump sum fee for conceptual design contribution
minimum	£0.050M
most likely	£0.060M
maximum	£0.075M

Table 6.9 The distribution estimate of the design-build contractor's lump sum fee for its conceptual design contribution

6.2.2.7 Step 7: Specification of the timing of the client's payments and the project revenue

Figures 6.25 and 6.26 indicate that the D-B option is likely to induce a significantly shorter project duration than that which would result if the Trad option was used. Consequently, a cash flow analysis for the project under the two contract strategy options was expected to provide informative results.

Figure 6.29 shows the inputs specified to model the timing of the client's payments under the Trad option. Interim payments are to be paid every four weeks for both work package 1 and 2.

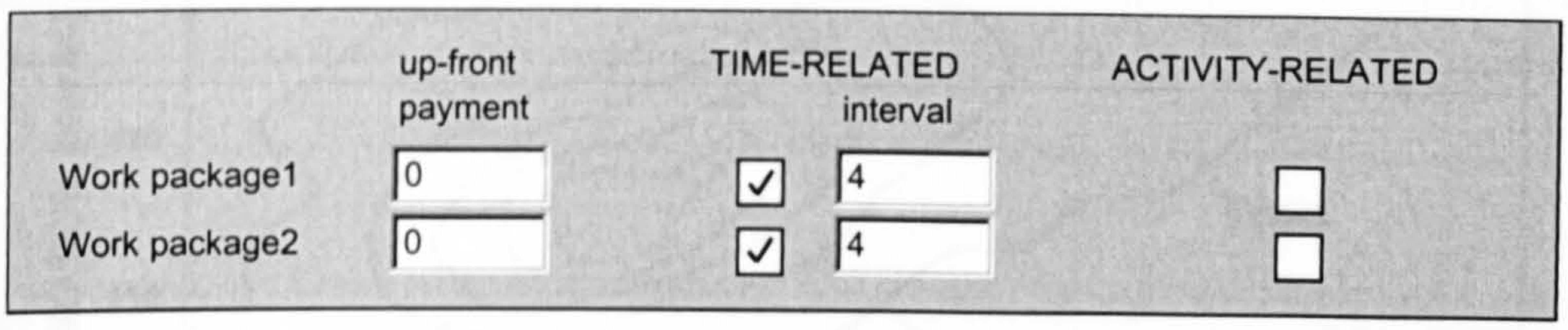


Figure 6.29 Specification of the client's timing of payments under the Trad option

Figure 6.30 shows the inputs specified to model the timing of the client's payments under the D-B option. During both work package 1 and 2, the client is to pay for each activity on completion.

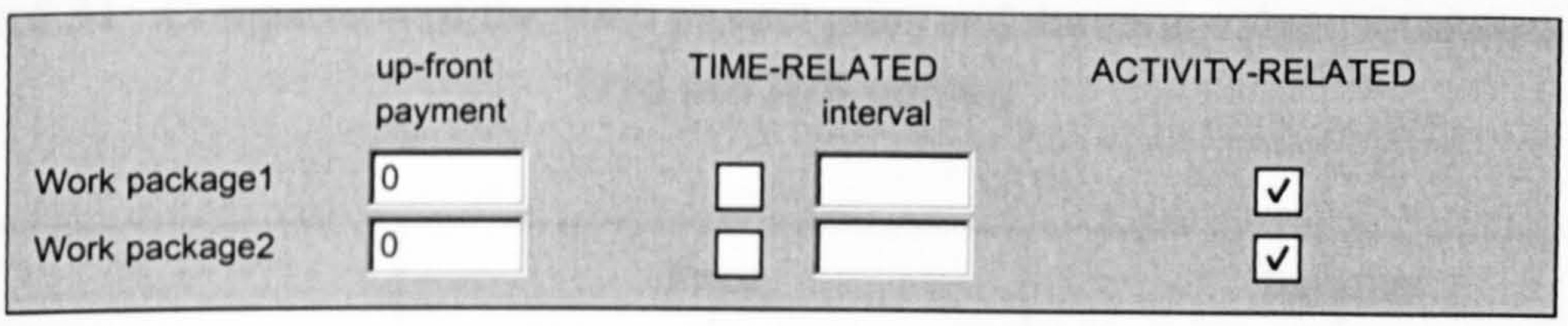


Figure 6.30 Specification of the client's timing of payments under the D-B option

With regards to project revenue, the user estimated that the client will receive an annual net income of £2M during its first five operational years. Although these estimates did not provide a precise or long-term representation of the project's operational performance, they provided a suitably accurate basis for comparison of the contract strategies' impacts upon the net present value of the project. Therefore these project revenue estimates were inputted for both the Trad and D-B option.

The discount rate was estimated at 8%.

6.2.3 Model output for the Trad and D-B options

The model performed 1000 simulated runs of the project using each of the two contract strategy options' set of inputs. Each option's project price and duration results are presented as contour plots in Figure 6.31. Table 6.10 provides a statistical comparison of each option's price and duration results.

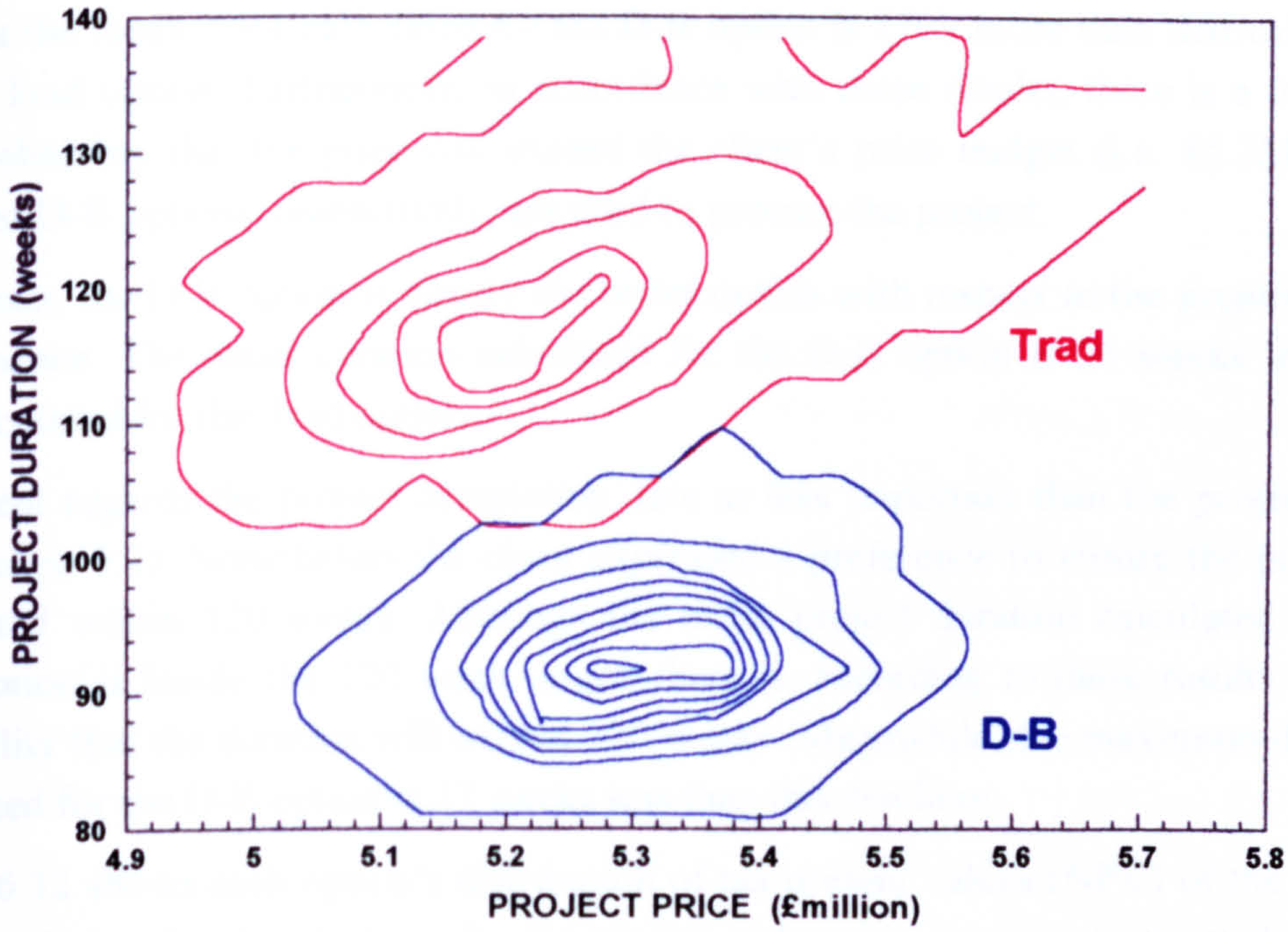


Figure 6.31 Comparison of the 1000 project price and duration values simulated for the Trad and D-B options

Statistical measure	Price		Duration	
	TRAD	D-B	TRAD	D-B
Minimum	£4.943M	£5.085M	104.0wk	81.1wk
Maximum	£5.701M	£5.510M	138.5wk	102.8wk
Mean	£5.218M	£5.286M	116.9wk	90.9wk
2.5th cumulative percentile	£5.014M	£5.138M	107.1wk	84.6wk
97.5th cumulative percentile	£5.500M	£5.440M	129.2wk	98.7wk
P(X > Budget)	0.23	0.42	0.29	0

Table 6.10 Comparison of statistical measures between the Trad and D-B contract strategy options

A significantly wider price range has been calculated for the Trad option and its maximum price value is nearly £200k more than the maximum price value calculated for the D-B option. However, the price values at the 2.5th and 97.5th cumulative percentile levels indicate that the majority of the 1000 simulated price values calculated for the Trad option cover the lower portion of its price range. This is reinforced by the fact that the mean price calculated for the D-B option is £70k more than that calculated for the Trad option. Furthermore, in accordance with these results, there is a 0.23 and 0.42 probability that the price will exceed the client's price budget (i.e. £5.3M) if the Trad and D-B options, respectively, are used to procure the project.

In contrast, the D-B option is clearly the better option with respect to the project's time performance. The mean duration calculated for the D-B option is 26 weeks less than that calculated for the Trad option.

The client regards the project completion date as less important than the project price (see section 6.2). Nonetheless the client expressed a preference to ensure the project is completed within 120 weeks. Although the mean project duration calculated for the Trad option is inside the 120 week target, there is, according to these results, a 0.29 probability that the duration will exceed 120 weeks. Meanwhile, the maximum duration calculated for the D-B option is 17 weeks less than this deadline.

Figure 6.32 shows each option's distribution of net present values (NPV) of the project which includes the client's price for the project and project revenue (estimated at £2M net annual income over a five year period). Since the project price is expected to be generally higher under the D-B option, it is apparent that the overall time saving induced by the D-B option, relative to the Trad option, can make a significant difference to the value of the project. The mean NPV for the D-B option is £60k more than that calculated for the Trad option.

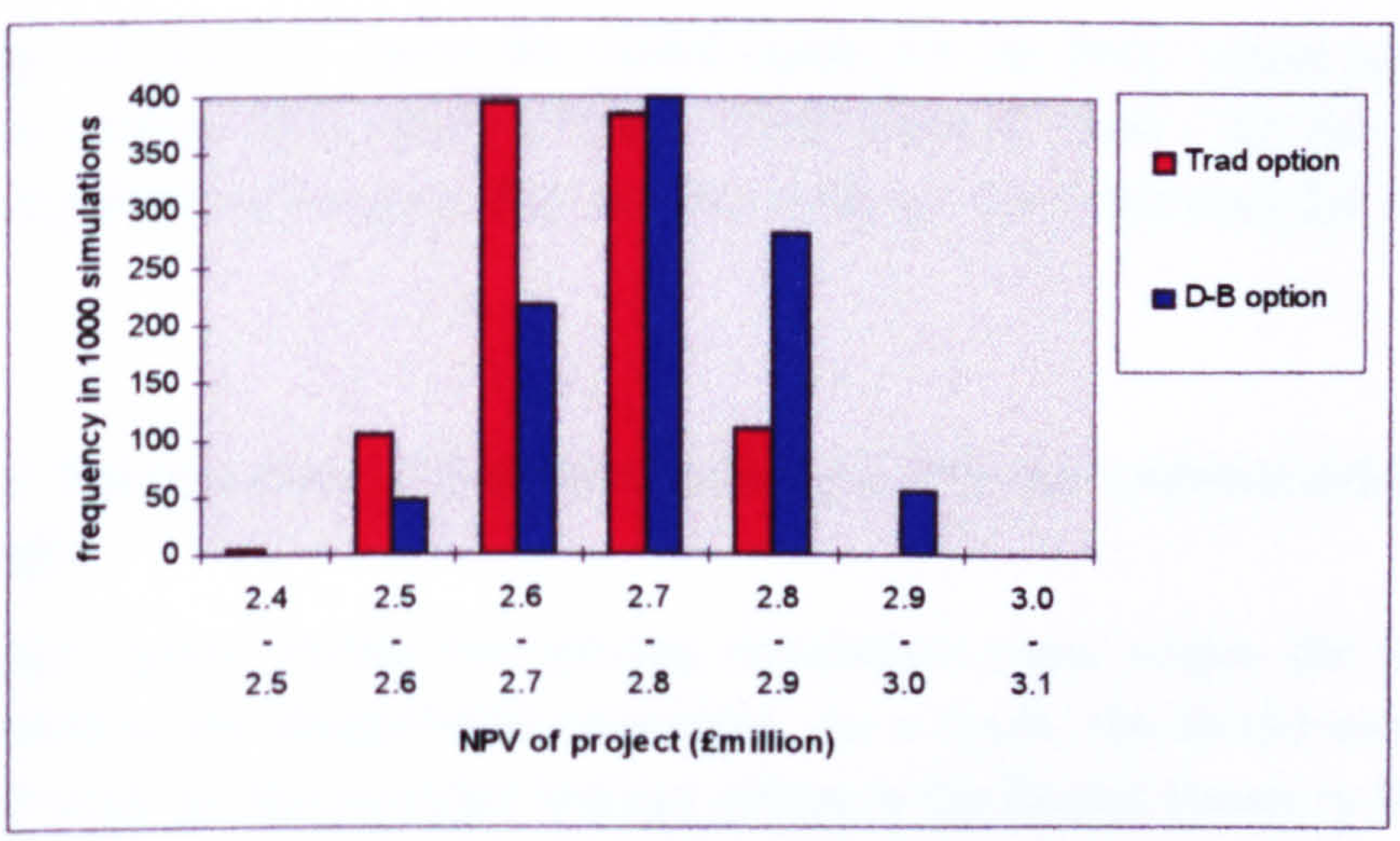


Figure 6.32 Comparison of the Trad and D-B options' distributions of net present values of project price and revenue

Given these results, the D-B option is preferred to the Trad option. However, since the client organisation is very keen not to exceed the price budget, the D-B option's 0.42 probability that the price will exceed the budget is regarded as unacceptable. It was therefore decided to investigate whether a variation of the D-B option could induce a lower price whilst retaining the advantages of the original D-B option. The contract strategy subsequently chosen to be evaluated is referred to as the 'D-B Target' option.

The revised D-B option is the same as the original D-B option with the exception that the client is required to remunerate the design-build contractor for the foundation activity using a target cost type pricing mechanism. In the original D-B option, the general risk related to the foundation activity was allocated to the contractor and both the activity's base cost and risk cost were to be included in a fixed price intended to cover all of the design-build contractor's costs. In contrast, the use of the target cost type pricing mechanism, in the revised D-B option, effectively shares the actual cost of the foundation-risk between the client and the design-build contractor.

In the D-B Target option, the other construction activities (frame; services and finishes) and detailed design activity are still grouped together as a fixed price package. The decision to isolate just the foundation activity and use a cost-based pricing mechanism was based upon the assumptions that this activity presented the greatest risk and because elements of this risk were uncontrollable. Therefore sharing the risk between the client and contractor was considered a more equitable arrangement and it reduced a contractor's probable inclination to include a conservative risk premium in a fixed price tender bid.

6.2.4 Model inputs for the D-B Target option

The following sub-sections report the model inputs for the D-B Target option which differ from the original D-B option's inputs. Input steps 4, 5 and 7 for the D-B Target option are not presented because they are the same as those reported for the original D-B option

6.2.4.1 Step 1: Specification of general details regarding the contract strategy's work packages

The D-B Target option utilises two pricing mechanism types within the same prime contract awarded to the design-build contractor. As a result, the model-user specified the division of work for this contract strategy option in the format shown in Figure 6.33. When prompted, the user specified a fixed price type pricing mechanism for work package 2 and a "Target cost (without GMP)" type pricing mechanism for work package 3.

Work package number	Contracting party label	Tender process	Pricing mechanism	Mngmt/Consultnts fee	
1	Agent	☐	☐	☑	Contractor
2	Contractor	☑	☑	☐	
3	Contractor	☐	☑	☐	

Figure 6.33 The general work package inputs for the D-B Target option

6.2.4.2 Step 2: Specification of the activities, risks and risk owners within each work package

The same activities and risks specified for the original D-B option were inputted again for the D-B Target option. However, the foundation activity is specified under the new option's third work package rather than the second work package. As with the original model, the user opted to analyse the general risk related to the foundation activity and also specified the design-build contractor as the owner of the risk. Nonetheless, the risk is effectively shared between the client and contractor. This is because the target cost pricing mechanism type requires the client to reimburse the contractor for all his costs, but then the difference between the contractor's costs and the predetermined target cost, whether it be a saving or loss, is divided between the client and contractor in proportions dictated by the predetermined sharing ratio (see Table 5.6).

6.2.4.3 Step 3: Quantification of activities and risks

The D-B Target option's estimates of each activity's base cost, base duration and each risk's additional cost and delay values were the same as those inputted for the original D-B option with the exception of the foundation activity estimates.

Section 6.2.2.3 presented the series of subjective assumptions used to reflect the potential impact of the D-B and Trad options upon the foundation activity's cost and time estimates. Following a review of these subjective assumptions it was decided that Stage 5 (Figure 6.23) of the estimates' refinement did not entirely apply to the revised D-B option.

Stage 5 made reference to the fact that the D-B option allocated the entire foundation-risk to the design-build contractor. Therefore it was perceived that the risk's additional cost values ought to be increased by a margin that reflected the contractor's probable inclination to overestimate the potential cost of the foundation-risk. Figure 6.34 shows the additional cost values used in the analysis for both the original and revised D-B options. It should be noted that all of the other estimates for the foundation activity remained unchanged.

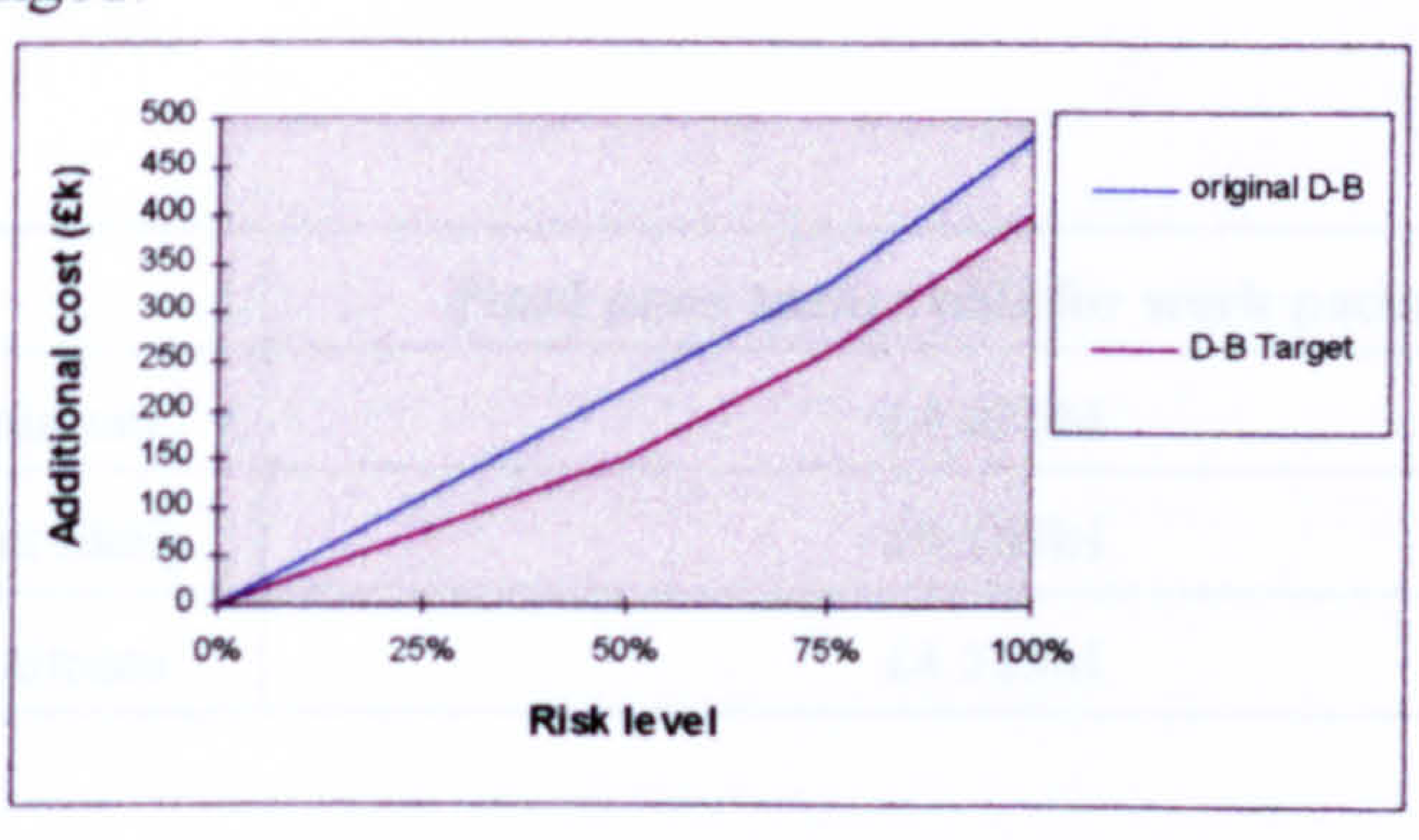


Figure 6.34 Comparison of the foundation-risk's additional cost values estimated for the original and revised D-B options

6.2.4.4 Step 6: Specification of tender bids

Two sets of tender bids had to be estimated. The first set was the triangular distribution of fixed price bids for work package 2 while the second set included distribution estimates of the target cost, target fee and a single estimate of the sharing ratio for work package 3.

Figures 6.35 and 6.36 show the design-build contractor's costs for work package 2 and work package 3, respectively. With regards to work package 2, the formulae used to derive the minimum, most likely and maximum fixed price bid values were the same as those used to obtain the fixed price bid values for the original D-B option (see Table 6.7). Table 6.11 shows the distribution of fixed price bid values inputted for the D-B Target option's work package 2.

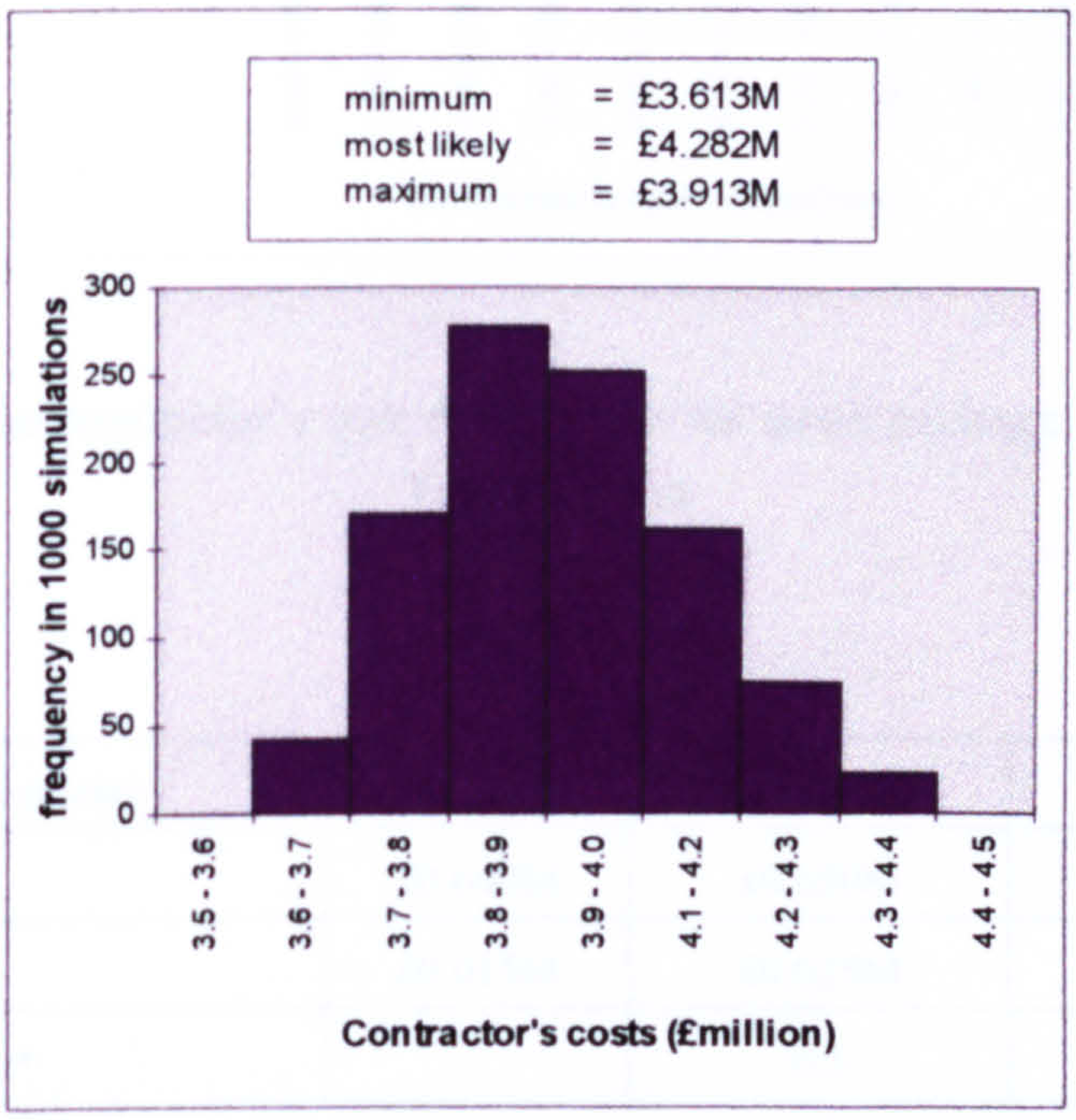


Figure 6.35 The contractor's cost distribution for work package 2 under the D-B Target option

	Fixed price tender bids for work package 2
minimum	£4.025M
most likely	£4.150M
maximum	£4.325M

Table 6.11 The distribution estimate of the fixed price tender bid for work package 2 under the D-B Target option

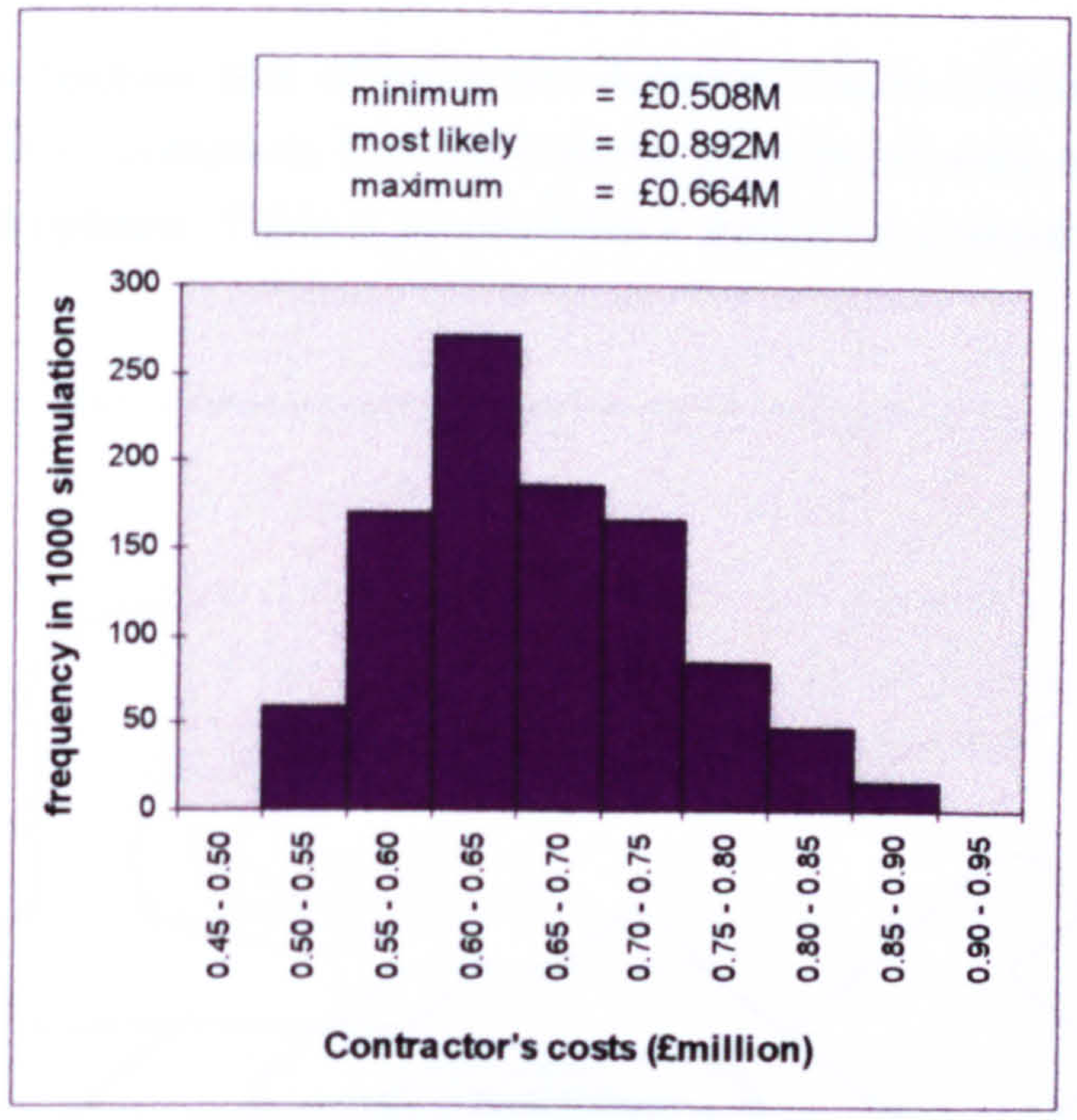


Figure 6.36 The contractor's cost distribution for work package 3 under the D-B Target option

Tender bid parameter	minimum	most likely	maximum
Target cost (T)	£0.640M	£0.650M	£0.665M
Target fee (F)	£0.015M	£0.025M	£0.040M
Sharing rate (b) *		0.5	

Table 6.12 The distribution estimates of the tender bid parameters for work package 3 under the D-B Target option

Table 6.12 reports the values of the tender bid parameters that were inputted for the D-B Target option's work package 3. The minimum, most likely and maximum target cost values correspond to the design-build contractor's cost for work package 3 at the 45th, 50th and 55th cumulative percentile levels. The minimum, most likely and maximum target fee values are equal to 2%, 4% and 6% of the design-build contractor's mean cost value for work package 3. The sharing ratio is fixed at 0.5 (i.e. any cost savings or losses relative to the target cost are shared equally between the client and contractor).

* the sharing rate (b) is fixed at a single value because it is assumed that this value is dictated by the client

6.2.5 Model output for D-B Target option

Figure 6.37 presents a contour plot of price and duration results simulated for the D-B Target option. Figure 6.37 compares it to the contour plots previously calculated for the original D-B and Trad options. Table 6.13 provides a statistical comparison of the three options' price results.

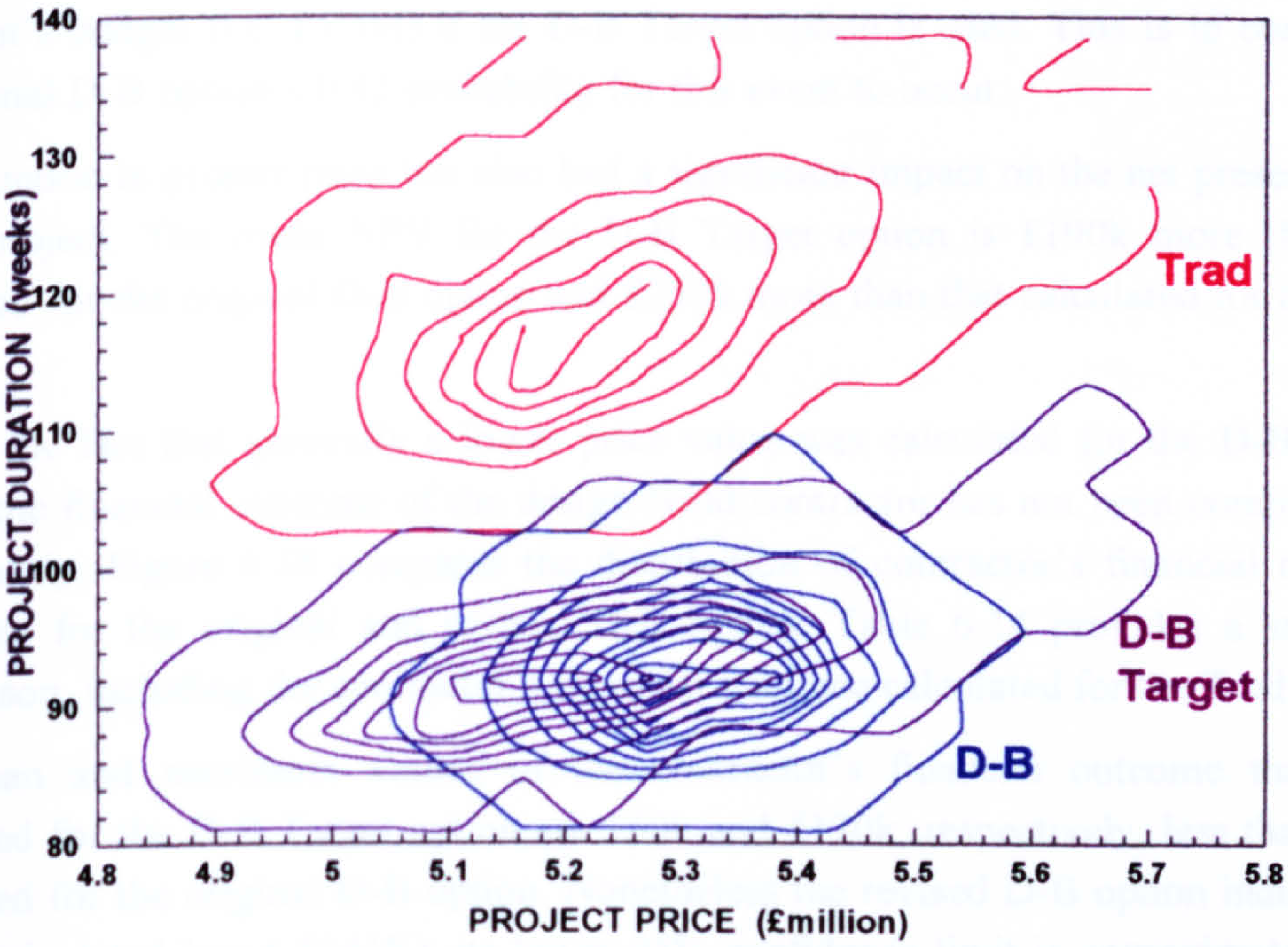


Figure 6.37 Comparison of the 1000 project price and duration values simulated for the Trad, the original D-B and the D-B Target contract strategy options

Statistical measure	TRAD	D-B	D-B TARGET
Minimum	£4.943M	£5.085M	£4.842M
Maximum	£5.701M	£5.510M	£5.640M
Mean	£5.218M	£5.286M	£5.175M
2.5th cumulative percentile	£5.014M	£5.138M	£4.930M
97.5th cumulative percentile	£5.500M	£5.440M	£5.460M
P(X > Budget)	0.23	0.42	0.17

Table 6.13 Comparison of statistical measures on the project price results calculated for the Trad, the original D-B and the D-B Target options

According to the results, the revised D-B option is expected to make significant cost savings relative to the original D-B option. The mean price value calculated for the D-B Target option is £110k less than that calculated for the original D-B option and £40k less than that calculated for the Trad option. Although the maximum price calculated for the D-B Target option is £130k more than that calculated for the original D-B option, according to the results, there is only a 0.17 probability that the project price will exceed the client's budget (i.e. £5.3M) if the D-B Target option is used. This is in contrast to the original D-B option's 0.42 probability for this event to occur.

The reduction in project price has also had a significant impact on the net present value of the project. The mean NPV for the D-B Target option is £190k more than that calculated for the original D-B option and £250k more than that calculated for the Trad option.

Despite the fact that generally a lower price value was calculated for the D-B Target option, the financial outcome of the design-build contractor has not been compromised significantly. Figure 6.38 compares the distribution of contractor's financial outcome calculated for the original and revised D-B option. Table 6.14 provides a statistical comparison, including the contractor's financial outcome calculated for the Trad option.

The mean and maximum values of the contractor's financial outcome that were calculated for the D-B Target option are £50k and £130k, respectively, less than those calculated for the original D-B option. Nonetheless the revised D-B option induced the lowest calculated loss (-£141K), its lower 95% confidence limit is approximately zero (i.e. break-even), in contrast to -£37K calculated for the original D-B option, and the probability that the contractor will incur a financial loss is slightly less than that calculated for the original D-B option.

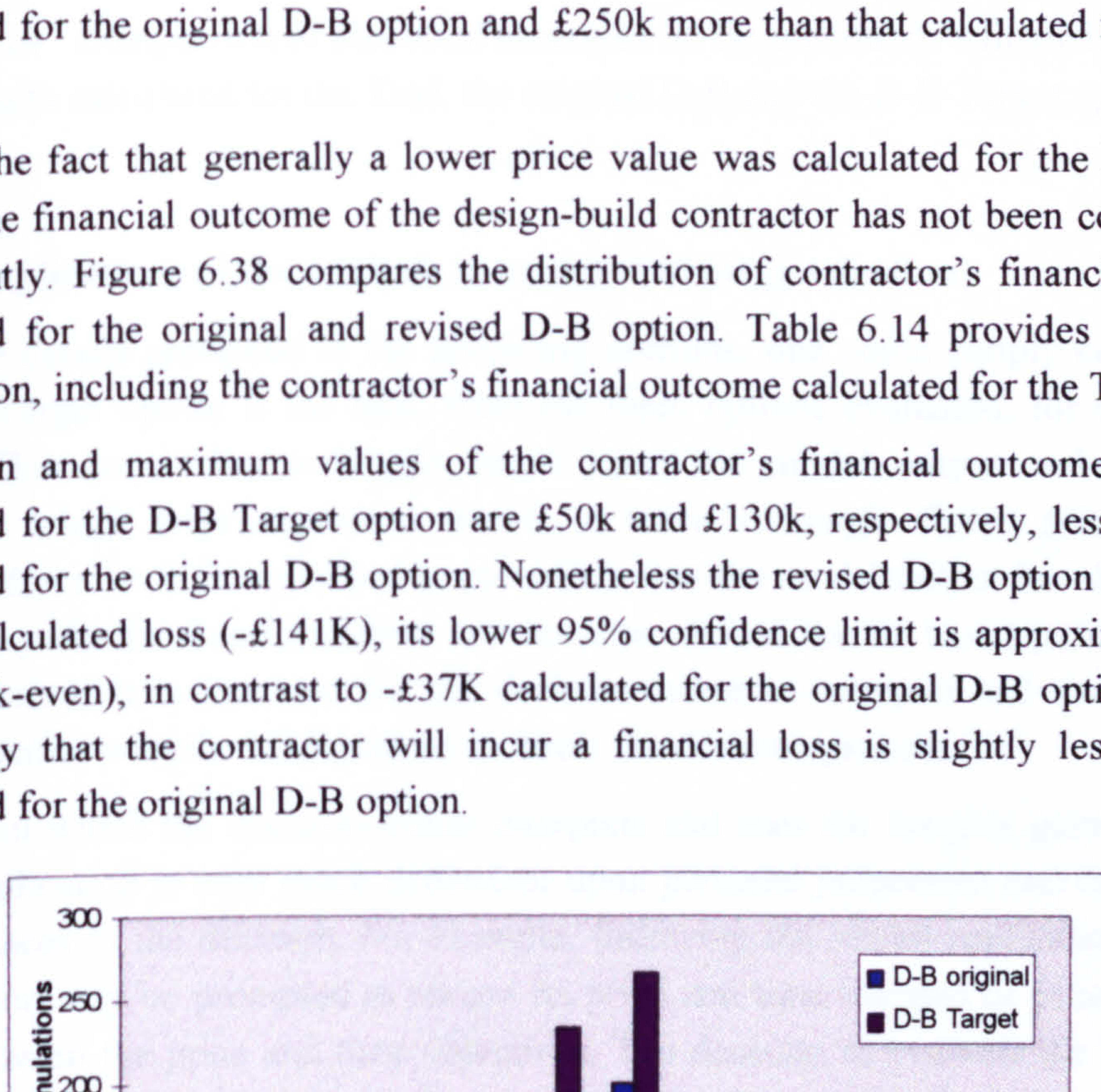


Figure 6.38 Comparison of the contractor's financial outcome under the original and revised D-B options

Statistical measure	TRAD	D-B	D-B TARGET
Minimum	-£0.172M	-£0.283M	-£0.141M
Maximum	£0.632M	£0.791M	£0.662M
Mean	£0.280M	£0.346M	£0.293M
95% confidence limits	£0.016M - £0.545M	-£0.037M - £0.729M	£0.007M - £0.579M
Prob. of financial loss	0.02	0.04	0.03

Table 6.14 Comparison of statistical measures on the contractor's financial outcome results calculated for the Trad, the original D-B and the D-B Target options

6.2.6 Implications of the analysis to contract strategy selection

Given the details presented in the preceding sections, one could simply conclude that the D-B Target option is the best, from the three options evaluated, for the example project. This conclusion is largely based upon the model output and the client's objectives which were expressed simply in terms of single figure price and time budgets. However, it is important to appreciate that the model output has derived from subjective judgement and therefore any decision should not be based purely upon the output. Instead it is intended for the decision-maker to interpret and use the model output together with the model inputs to direct the decision process.

The way in which the decision-maker interprets and uses the insights gained from the model application is very much dependent upon personal judgement and the particular circumstances of the decision. For example, following the model application the client organisation may be prompted to review its price and time budgets or even its priority rating between the price and time objectives. The decision to evaluate the D-B Target option was a calculated judgement based upon the analysis of the Trad and original D-B options. However, it may have been equally valid to have evaluated alternatives such as a D-B option where the entire foundation-risk is allocated to the client or a D-B option where all of the risk related to detailed design and construction work is shared using a target cost mechanism.

The process of applying the quantitative approach is intended to provide insights which are as valuable as the those provided by the model output itself. Table 6.5 presented a series of subjective distinctions between the Trad and D-B options which were reflected in each option's model inputs. Figure 6.23 also demonstrated how the foundation activity's estimates were refined for the Trad and D-B options to incorporate several of the subjective assumptions cited in Table 6.5. It should be noted that each model input, even each estimate refinement as featured in Figure 6.23, may be derived from an application of quantitative or qualitative analytical techniques. Therefore the model inputs, in addition to the model output, equate to results from an application of the quantitative approach to contract strategy evaluation.

It is inefficient to perform analysis to ascertain the sensitivity of the output to each input owing to the large number of inputs. Sensitivity analysis for certain inputs may be necessary and useful. However, the decision-maker's time and effort may be expended more wisely by reviewing the subjective assumptions accounted for in the model inputs. A major aim of the quantitative approach is to encourage the contract strategy selectors to rationalise their intuitive, qualitative assumptions about contract strategy options.

It is expected that, before any analysis was undertaken, the decision-maker would be confident that the Trad option would induce a significantly longer project duration that the D-B option. However, it is probable that the decision-maker would be less assured about the two options' relative, potential impacts upon the project price before any analysis was undertaken. One may hypothesise that the decision-maker's uncertainty could stem from the following two contrasting, general, intuitive assumptions:

1. the Trad option requires the client to bear the cost of any risk related to the foundation activity while these costs are borne by the contractor under the D-B option;
2. Design-Build type contract strategies generally induce a higher price for a project than Traditional type contract strategies.

Owing to the explicit and quantitative nature of the model inputs, the decision-maker was compelled to rationalise the two previously-cited assumptions as well as other subjective distinctions between the Trad and D-B options. As a result, it was possible to accumulate a series of contrasting, qualitative assumptions and obtain an explicit overview of what all the assumptions amount to, in very tangible and appropriate terms; units of cost and time. Consequently, the analysis of the Trad and D-B options is likely to reduce the decision-maker's uncertainty about the two options' relative, potential impacts upon the project price.

It is has been demonstrated that a considerable amount of useful information can be gained from evaluating contract strategy options in units of cost and time. In addition to project price and duration, it is possible to calculate the values of a variety of other variables such as a contractor's financial outcome and the net present value of the project. A contract strategy's potential ability to induce a project performance that satisfies the client's price and duration objectives can be measured directly. It is also possible to compare, explicitly, several contract strategies' potential impacts upon a project's performance.

The use of probabilistic techniques certainly leads to valuable measurements. The advantage of estimating a distribution of values, rather than a single value (e.g. mean), for each cost/time element was illustrated by the Trad option's expected effect upon the project duration. The mean project duration value calculated for the Trad option was less than the client's prescribed target of 120 weeks, yet the distribution of duration values indicated that there was a 0.3 probability that the target would be exceeded.

Another aim of the quantitative approach is to make the assumptions explicit so that they are open to criticism, particularly from the decision-maker. As the actual project events unfold the decision-maker may be able to attain a more objective perception about the validity of his/her assumptions. Therefore contract strategy decisions on subsequent projects may be less subjective.

This section has provided a brief overview of how the model application for the example factory building may assist the contract strategy selector. It has emphasised the view that the quantitative approach is not intended to produce answers, but to provide guidance to the decision-maker's inevitable subjective judgement.

It is possible to develop the model so that it ascertains the optimum contract strategy from those to which the model has been applied for a particular project. This is possible because the model could measure the model output, for each contract strategy evaluated, with respect to certain criteria prescribed by the user. These criteria could relate to, for example, acceptable probabilities of exceeding budget levels and the minimum permissible financial outcome for a contractor. Although the introduction of automation of this type offers definite advantages, it may impair, firstly, a decision-maker's appreciation of the assumptions underlying an analysis and, secondly, a decision-maker's impetus to perform iterative analyses. As a result, decision-making automation may disable the learning potential of the quantitative approach.

7. Conclusions

Numerous sources have identified deficiencies that exist in the industry's typical approach to contract strategy selection (see section 2.3.2). The use of inappropriate contract strategies results in inefficient construction, with the associated time delays and financial penalties.

In this thesis a quantitative approach to contract strategy evaluation has been developed to eliminate the deficiencies in current practice and induce better contract strategy decisions. The key observations and insights gained from the research are presented in section 7.1. Section 7.2 is a discussion about how the research might be further developed in the future. A major item within the discussion concerns the underlying research aim which is to improve contract strategy selection in the long-term.

7.1 A review of the research observations and insights

The initial research objective was to gain an understanding of both the nature of contract strategy selection and the industry's typical approach to this decision problem. This understanding was gained from literature and interviews with fourteen industrialists.

It appeared that both the construction industry and academia can be accused of over-simplifying the decision problem. The desire to establish a set of generally-applicable decision rules is considered to be a major contributory factor to the over-simplification.

Several deficiencies appeared to exist in the industry's typical approach to contract strategy selection. The existence of these deficiencies was supported by the survey of industrialists. The deficiencies include:

- limited appreciation of the decision options;
- failure to set clear, realistic and balanced price, duration and quality targets;
- failure to wholly rationalise decisions in terms of the client's primary objectives;
- unstructured and imprecise decision mechanisms;
- lack of explicitness and transparency in the decision mechanism; and
- failure to account for the uncertainty inherent in contract strategy selection.

The research set out to develop a new improved methodology to contract strategy selection and implement it in a model. The general requirements of a new methodology were reflected in the research objectives. It was aimed to devise an approach that:

- was attuned to the nature of the decision problem;
- can and will be applied by the industry (i.e. is feasible and practical);
- aids a decision-maker to make rational contract strategy decisions; and

- has the potential to improve the industry's knowledge about contract strategy selection.

The research provided many insights into the extent to which these four objectives were met. The key insights are presented below under headings that refer to each objective.

Attuned to the nature of contract strategy selection

- The existing contract strategy decision-aids were not attuned to the nature of the decision problem. They did not address, in sufficient depth, the interrelationship between a contract strategy, a project's circumstances and a client's objectives. Essentially, they all comprised fairly generalised decision rules which often differentiated between contract strategies using criteria that did not equate to rationalisation in terms of the client's primary objectives (i.e. project price, duration and quality targets). For example, many existing contract strategy decision-aids ascertain the appropriateness of a contract strategy from, amongst other criteria, a client's preference to retain or transfer the bulk of project risk. Other than imposing a structure on the decision process, the majority of the existing decision-aids appear to incorporate the same set of deficiencies that exist in the industry's typical approach to contract strategy selection.
- The quantitative approach was developed to address the nature of contract strategy selection and thereby to eliminate the deficiencies in current practice. The quantitative approach aims to discipline a decision-maker to address the interrelationship between a contract strategy, a project's circumstances and a client's objectives. The quantitative approach requires a decision-maker to reflect his/her perceptions about a contract strategy's likely impact upon a project in probabilistic estimates of the project's constituent cost and time elements. The estimates are then combined to give probabilistic cost and time measures of project performance that reflect the potential impact of the particular contract strategy that was evaluated. Therefore the appropriateness of a contract strategy, including its risk allocation, is rationalised in terms of the client's primary objectives rather than in terms of criteria such as the client's preference to retain or transfer the bulk of project risk.
- In addition to simulating a project's cost and time performance, the quantitative approach involves simulating particular features of each contract strategy that is evaluated (e.g. work packaging, risk allocation, pricing mechanism). Although, in theory, the quantitative approach may be used to evaluate any contract strategy, for practical reasons, not all contract strategy features can be simulated by a model that provides a framework with which to apply the quantitative approach. For example, it is impossible to simulate the precise organisational structure imposed by a contract strategy. It is also difficult to establish a generic model framework that is capable of simulating all possible variations of risk allocations and pricing mechanisms.

Feasible and practical

- The feasibility of the quantitative approach was supported by a number of literature-reported cases where prospective contract strategies for a project had been differentiated in terms of their expected impacts upon the cost and time performance of the project (Chisnall, 1991; Pedwell *et al.*, 1996).
- The interviewed industrialists expressed both positive and negative views about the feasibility of the approach. As expected, the majority of the industrialists were initially very sceptical. However, the new approach was received more positively by some as they became familiar with its principles. The six who completed questionnaires indicated that, in their view, the quantitative approach was workable.
- There is a need to recognise that the quantitative approach has a limitation that may prevent its use in practice. This limitation relates to the large amount of data that a user is required to acquire and input when applying the quantitative approach, particularly in the format adopted in the refined model. Furthermore, some of this input data may be difficult to obtain because:
  - the data is unavailable at the outset of a project; or
  - it involves estimation of variables that have little intuitive appeal.
- The majority of the interviewed industrialists expressed reservations about the practicality of the quantitative approach. Some industrialists claimed that there would be insufficient time and other resources available at a project's outset to apply the quantitative approach. Other industrialists perceived that its application would be a waste of valuable resources because the approach relies upon very speculative information.

Useful decision-aid

- The theoretical applications of the quantitative approach (reported in chapters 3 and 6), together with the applications performed by the six industrialists (reported in chapter 4), demonstrated that an application of the quantitative approach leads to a series of outputs that may aid contract strategy selection. For example, the output of the refined model includes a distribution of project price, project duration and the financial outcome of parties contracted by the client. Several of the interviewed industrialists indicated that the price and duration results of the quantitative approach provided a useful overview of the likely differences between contract strategies.
- The decision-maker can analyse and test his/her theories and assumptions relevant in each contract strategy decision problem by varying either the nature of the input variables or the values estimated for the input variables. Therefore the process involved in arriving at the inputs may prove to be very insightful. In fact it would

not be surprising to find that the process involved in applying the quantitative approach provides more decision-making insights than its final outputs.

- Some of the interviewed industrialists stated that the quantitative approach served a useful purpose in breaking contract strategy selection down into a series of sub-decisions where each sub-decision was an appraisal of a contract strategy with respect to a project's specific cost and time element (e.g. design cost, tender process duration, etc.). Other industrialists commended the quantitative approach for its focus upon contract strategy decisions made at the outset of projects. These industrialists regarded good, early project decisions as prerequisites for a successfully-managed project.

Potential to improve knowledge on contract strategy selection

- Two industrialists who completed questionnaires recognised the need to question their intuitive judgement once shown the price and duration results calculated from their estimates of cost and time elements that reflected the likely impact of the contract strategies they had evaluated. This result is an indication of the potential to improve an individual's knowledge about contract strategy selection by making their decision process structured and transparent.
- The reliability of the analysis will always be subject to criticism, especially the output to the refined model because it is the accumulated product of a large number of subjective estimates. Many of the interviewed industrialists expressed reservations of this type. However, it is intended that the rigorous, structured and explicit nature of the quantitative approach enables the criticism and debate to be directed to the theories and assumptions that underlie the model inputs and outputs. It is believed that this may lead to less subjective and, subsequently, better contract strategy decisions.

7.2 Scope for further development of the research

The research described in this thesis has led to the development of a probabilistic model which assists in the decision-making associated with contract strategy selection. The model represents a quantitative approach, which is sufficiently developed to have been applied to realistic examples in its present form. Discussion on scope for further development will focus on the following aspects:

- practical considerations for model application;
- extensions to the scope of the model in terms of flexibility in range of inputs; and
- extensions to the model which would enable it to be used as a record of experience.

7.2.1 Practical considerations for model application

The questionnaires employed in the empirical research are considered to have provided industrialists with a very useful introduction to the quantitative approach. Some of the industrialists who completed questionnaires may be sufficiently familiar with the underlying principles to apply the quantitative approach to an actual project. This is clearly the next step in the research.

Initially, it is advisable to use the model in the fairly simple manner demonstrated with the hypothetical tunnel project in Chapter 6. In this example the objective differences between the contract strategies (i.e. each option's risk allocation and pricing mechanism type) were focused upon. In contrast, application of the model to the second example project in Chapter 6 (i.e. factory building) took a greater account of the subjective assumptions used to distinguish between contract strategies. This application also indicated that technical methods may be used to decide upon the values to be used for model inputs. It is arguable that some of the subjective assumptions accounted for in the analysis for the factory building project are too speculative and uncertain to quantify. However, this speculation and uncertainty could reduce as a decision-maker accumulates more experience in the application of the quantitative approach.

There is a vast amount of literature that present abstract theories about the relative advantages and disadvantages of broadly-defined contract strategy types (e.g. comparing 'Traditional' with 'Design-Build' - see section 2.2.4) and about the allocation of project risk (see section 2.5.1.1.1). The research has demonstrated that the application of quantitative techniques to contract strategy decisions enables these theories to be put into context and tested. The tests are not definitive, but they make the decision processes transparent and thereby encourage rigorous and rational decision-making. It should be noted that the quantitative techniques, and the principles justifying their use, apply to any decision problem, not just contract strategy selection for construction projects.

At this stage in the research, priority has to be assigned to instilling the fundamental principles of the quantitative approach into a decision-maker's conventional approach to contract strategy selection. The fundamental principles refer to the process of translating subjective assumptions into cost and time estimates and being able to justify the resultant estimates. Consequently, suggestions for work in the immediate future include:

- review the user-comprehension of the model and possibly write a manual to accompany the model;
- work alongside a contract strategist during an application of the model to an actual project; and
- report and analyse the results of the case study.

It has already been acknowledged that it is impossible to obtain a conclusive measure of the feasibility and utility of the quantitative approach, nor can it guarantee selection of appropriate contract strategies on future projects. Nonetheless, it is presumed that a meaningful measure could be gained if the approach was applied by practising contract strategists to a series of projects over a long period of time.

7.2.2 Extensions to model flexibility/complexity

Chapter 5 described the latest model designed and constructed to facilitate application of a quantitative approach to contract strategy evaluation. Chapter 5 reported that many of the refinements made to the prototype model (e.g. correlation between cost and time, simulation of a contract strategy's risk allocation) were warranted given the compromises made during the development of the prototype model and the insights gained from the empirical research. Meanwhile other refinements (i.e. calculation of a project's NPV and the financial outcome of contractors) were regarded as particularly valuable and relevant model-additions.

However, the refined model could be developed further. For example, it may be extended in the following ways:

- The decision-maker may gain valuable insights if the model incorporated a framework that enables each contract strategy's organisational structure to be modelled in more detail. Obviously, the aspects of a contract strategy's organisational structure that are outside the control of the client or not imposed by a contract strategy may not be modelled. However, it may be possible to obtain an accurate model of the structure within the client's organisation, including the client's advisors, for each contract strategy option. It may also be possible to model the contractual interfaces between contracted parties and the client's team.
- The flexibility of the model may be increased to allow more pricing mechanism types to be modelled. For example, the current model simulates only one variation of a target cost type pricing mechanism. Furthermore, there is no facility to simulate a target time mechanism or simulate a mechanism that utilises both target cost and time levels. The model similarly constrains the mechanism options for management/consultant fees.
- It would be advantageous to introduce a time dimension into the analysis. The quantitative approach is intended to be applied at the outset of projects before any critical contract strategy-related decision is made. Therefore the results reflect the level of certainty prevalent at the project outset. However, it is possible to use the same analysis to survey how each evaluated contract strategy will affect the level of price certainty throughout the project. This output is governed by a contract strategy's pricing mechanism type(s) and the timing of a contract strategy's tender process(es) because the values of a pricing mechanism's parameters are generally fixed at the corresponding tender process. Since price certainty is a commonly-cited selection criterion, the calculation is expected to be a valuable addition.

The above list is not a definitive set of possible model-extensions. There is scope to add a variety of features to the refined model. However, Ward (1989) highlighted that a model's clarity, flexibility and convenience (i.e. constructive simplicity) tends to be in conflict with the model's completeness. Ward (1989) and Chapman and Ward (1997) suggest that constructively simple models are more likely to be developed into complete and valid models.

Chapter 6 demonstrated that application of the refined model can produce meaningful results and is capable of providing aid to contract strategy selection. It is acknowledged that further features could be added to the refined model. However, in light of the comments by Chapman and Ward, it is reasonable to assume that the refined model is sufficiently complex. Therefore it is believed that that any potential developments to the refined model should not be addressed until the current model has been tested thoroughly.

7.2.3 The model as a record of experience

ICE (1996) claimed that improved efficiency in the construction industry may be achieved by, amongst other things, "adoption of continuous improvement culture and more systematic learning from project successes and failures". Simon *et al.* (1997) acknowledged that experience can be captured effectively and efficiently by making objectives, decisions and estimates explicit so that they can be reviewed once the relevant events have transpired. The quantitative approach and the model designed to facilitate application of the approach adhere to these principles. However, with regards to explicitness and the learning process, the model could be improved in time by the development of a database. For each project the database could store:

- quantitative input and output for each contract strategy option to which the approach is applied;
- details of each contract strategy evaluated;
- the subjective assumptions underlying the inputs that make reference to the perceived distinctions between contract strategies and to particular project details; and
- information resulting from a review of each completed project.

A database used in this way could lead to the identification of generalities on a personal level or individual organisation level. The author has serious doubts about developing a knowledge-based contract strategy decision-aid that will be valid and perceived as insightful throughout the industry. Nevertheless it is perceived that the likelihood of such a model being developed is improved if individual decision-makers learn to select contract strategies on a less subjective and more case-specific basis.

Before a database can be built it is necessary to establish the type of data that will be useful and how best the data can be stored for effective retrieval (Chapman and Ward, 1997). This information will become apparent once the quantitative approach is put into practice.

It is anticipated that it will take time before a decision-maker is comfortable with, and competent at, application of the quantitative approach to contract strategy evaluation. However, owing to the importance and complexity of the decision problem, as a long-term solution it is considered to represent a valid proposal.

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APPENDICES

The appendices are on the enclosed compact disc.

Compact Disc: Table of Contents

Appendix A	Questionnaires designed for the empirical research
Appendix B	Interview notes
Appendix C	Questionnaires completed for the empirical research
Appendix D	The refined model