THE TREATMENT OF UNCERTAINTY IN CONSTRUCTION PRICE MODELLING

BY

HENRYK ANDRZEJ LEON STREZ

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ABSTRACT

The purpose of this thesis was to acquaint the reader on the nature of the uncertainty present in construction price forecasting and to introduce an environment that has the ability to integrate these uncertainties with greater consistency than that possessed by available price models.

The objective of this thesis was to establish that uncertainty can be explicitly treated in price forecasting models. This would have two benefits to concerned parties. Firstly, the effectiveness of price forecasts could be improved as provision could be made for any uncertain variable. This will be of great benefit to the client, as a more accurate assessment of the building process could be established at an earlier stage of the design process. Secondly, the price forecast will be more useful to quantity surveyors, architects and clients, as it would 'quantify' the extent of the uncertainty which could be provided for in a more meaningful manner.

In order to establish that existing price models do not deal with the uncertainty present at the time of forecasting, the price models used by practitioners were evaluated against the different types of uncertainty found at the different stages of the price forecasting process. Once this had been established, eight techniques that have the ability to treat various forms of uncertainty, were presented. After analysing the techniques abilities to cope with the uncertainties associated with price forecasting, it was established that certain of these techniques do have the ability, and are suitable, to be incorporated into the price forecasting process.

From the results of a questionnaire survey conducted on quantity surveying offices in South Africa, it was found that the price models used by practitioners do not take uncertainty into account, and have in fact, the potential for uncertainty inducement.

Some of the uncertainty found to be present in the preparation of a construction price forecast include the lack or incompleteness of design information, the uncertainty in the communication of design information, the variability in the data used by quantity surveyors and, the uncertainty in the choice of price model during the different stages of the design process.

As a possible solution to the problem of uncertainty, an expert system environment, utilising a three-dimensional classification of uncertainty, has been proposed. It has been proved that this environment has the ability to cater for the uncertainty associated with the price forecasting process, as well as having the attribute of providing the user with the reasoning behind the logic that the expert system has followed, a characteristic not possible with the traditional forms of price models.

From the findings of this thesis, it can be concluded that the methods of price modelling used by quantity surveying practitioners, are unable to take uncertainty into account effectively. It can also be concluded that an expert system environment has the ability to handle the different forms of uncertainty found at the various stages of construction design. The proposed model is conceptual in nature and has not been tested in practice. It is therefore recommended that further research be carried out in this field, with the aim of producing a construction price forecasting expert system which utilises the proposed three-dimensional classification of uncertainty.

DECLARATION

Much of the material contained in this research report stems from guidance provided by my supervisor, Professor P.A. Bowen and is, in fact, the subject matter of his research towards a higher degree. Futhermore, the data emanating from the questionnaire survey is a result of a collaborative effort on the part of H. Strez, S. Jadav, K. Hall, C. Procter and our joint supervisor, Proffesor P.A. Bowen.

Given the nature of the comlementary research, overlaps are unavoidable.

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Inception and brief stage

The preparation of the general outline of the client's brief, and a plan for future action.

Feasibility stage

To provide the client with a financial appraisal and recommendation in order that he may determine the form in which the project is to proceed.

Sketch design stage

Determine the general approach to layout, design and construction. Preparation of particular sketch proposals, outline specifications, and cost comparisons.

Detail design stage

To obtain final decisions on every matter related to design, specification, construction and cost.

Tender action stage

The preparation of working drawings, bills of quantities, and tender documents.

Price modelling

Price modelling is the symbolic representation of a system expressing the content of that system in terms of the factors which influence its price (after Ferry and Brandon, 1988).

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CHAPTER 1

INTRODUCTION

1.1 LITERATURE REVIEW ON THE TREATMENT OF UNCERTAINTY

Although uncertainty has been acknowledged by many authors (Higgin and Jessop, 1965; Beeston, 1986; Erwin *et al.*, 1991; Newton, 1991a), the successful treatment thereof has not yet been documented. The acceptance of the concept of uncertainty occurred between 1925 and 1935, with the publications of Heizenberg identifying the inherent uncertainty associated with certain measurements (Reece, 1979). As an introduction to this literature review, it is appropriate to consider uncertainty as a philosophical problem, as put forward by authors such as O'Connor (1957) and Gallie (1957). Gallie (1957, p.7) state that;

> "no physical law, and no combination of physical laws, is intended to provide or is capable of providing an absolute detailed forecast of the development and outcome of any particular concrete situation. Consequently, no matter how well we are equipped with laws of the kind which physics provides, we shall always be left with some degree of uncertainty or other as regards the actual concrete outcome of any situation which faces us".

Although the above statement may be true, there exists a strong psychological desire for certainty in order to gain a feeling of security and confidence in the external world, with a resultant reasonable happiness (Reece, 1979). Much has been written about this psychological need for certainty by authors such as Kahneman and Tversky (1982), Tversky and Kahneman (1974, 1981), Mack (1971), Dixon (1985), Wernerfelt and Karnani (1987) and Reece (1979).

Mack (1971), in an attempt to measure the psychological 'cost of uncertainty' lists three forms of 'costs' that uncertainty may cause. The first is the 'uncertainty discount', which "derives from a preference for sure bets which sets uncertain ones at a discount" (Mack, 1971, p.3). The second is 'befuddlement', which Mack (1971, p.5) explains as follows;

> "Uncertainty may cause the action that is finally chosen to be badly executed. A situation heavily shrouded in uncertainty may produce poorly motivated follow-through, shilly-shallying, and lackadaisical action. Action haunted by uncertainty also may be unconvincing to others and therefore ineffective."

The third cost of uncertainty results from the tendency of uncertainty to provoke "disadvantageous externalities - the impacts of an act other than those of direct concern to the decision maker" (Mack, 1971, p.6). The second and third 'costs' imply a deterioration in decision behavior, and are undesirable and sometimes unavoidable (Mack, 1971).

Linked to the psychological effects of uncertainty on human behavior, is the way in which the communication between the sender and receiver of a message can be uncertain, as well as the communication, or transfer of information that contains uncertainty. Shannon and Weaver (1949) were among the first authors to provide an explanation of the uncertainty present in the transfer of information, with their results being used by authors such as Berger and Bradac (1982), Hardcastle (1990), Cronkhite (1976) and Berlo (1977a) to acknowledge and 'treat' the presence of uncertainty in given situations. Stated briefly, the Shannon/Weaver model (1949) acknowledges the presence of 'noise' (both physical and psychological) within the communication process which leads to uncertainty in the transferal of a message from the sender to the receiver. Berger and Bradac (1982, p.7), in an explanation of uncertainty in information transfer, give two kind of uncertainty, which they explain as follows;

> "First, there is what we will call *cognitive uncertainty*. This term refers to uncertainty we have about our own and the other person's beliefs and attitudes. Second, *behavioral uncertainty* concerns the extent to which behavior is predictable in a given situation".

In an attempt to quantify uncertainty, authors such as Lindley (1987), Henkind and Harrison (1988), Shortliffe and Buchanan (1984), Zadeh (1965), Bennet and Ormerod (1984), and Shore (1978) have provided several approaches and techniques for the handling thereof. Some of these techniques include probability theory, bayesian theory, certainty factors, fuzzy logic, decision tables, possibility theory and simulation.

Many authors have published works dealing with, *inter alia*, the nature and treatment of uncertainty, with much work being done in the fields of medicine and the engineering sciences. In this regard, the contributions of Shortliffe (1976), Buchanan and Feigenbaum (1978), Pople (1982), Buchanan and Shortliffe (1984), Spiegelhalter (1987) and Holtzman (1989) are worthy of note.

Higgin and Jessop (1965) were among the first to recognise the existence of uncertainty in the building industry. Higgin and Jessop (1965) identified two major characteristics that needed to be incorporated in any map or model of the building process as 'independence' and 'uncertainty'. Since then, research into the treatment of uncertainty includes the work done by Scott *et al.* (1988), who dealt with the nature and use of uncertainty in property valuation, Skitmore *et al.* (1989) on the nature of uncertainty in project management, Marshall (1988) on the treatment of risks and uncertainties in the financial evaluation of building projects, and Toakley (1989) who compiled a critical review on the uncertainty in the building procurement process.

In assessing the conventional approach of price modelling, Newton (1991b, p.1) states;

> "The conventional approach to building cost estimation is to produce a single figure estimate. The problem facing the estimator is to predict an estimate figure which bears an acceptable relationship to the actual cost to be incurred. Various factors (not least of which is the fact that cost estimates are produced well in advance of the time when cost actually are incurred), contribute to the mismatch between estimate cost and actual cost. The extent of the mismatch is termed error. In adopting a single figure estimate, conventional techniques effectively mask the uncertainty attached to the amount of error in a cost estimate. It is this simple omission which makes a mockery of the conventional cost estimating process."

The increasing need by clients for a more accurate and 'certain' projection of the building price (Hodgetts, 1987; Taylor, 1984; Newton, 1991a) has led to what Brandon (1982) referred to as a 'paradigm shift' from the traditional methods of modelling the price of buildings. With regards to price modelling, Newton (1991a) provides a list of 56 published authors that have contributed to research carried out in the field of cost and price modelling and although not exhaustive, it does provide an adequate overview as to who has done what in cost and price modelling over the past thirty years. The 'paradigm shift' highlighted by Brandon (1982), has led to a greater emphasis being placed on 'influencing variables', and the probability of the outcome of the forecast, rather than the 'deterministic' approach that has been followed in the past. Newton (1991a, p.102), in evaluating the uncertainty associated with forecasting states;

> "The nature of cost is known to be uncertain. The only question is whether that uncertainty is best formally assessed in the model, or dealt with intuitively by the user. The classification here distinguishes between those models without a formal measure of uncertainty (deterministic) and those with (stochastic). Formal measures of uncertainty may be such metrics as the associated coefficient of variation (as in regression analysis) or the cumulative frequency distribution (as in Monte Carlo simulation)."

In concluding this review, Newton (1991b, p.3) offers two reasons why a 'theory of uncertainty' in price modelling is needed.

> "Firstly, many, large and complex projects have varied considerably in cost. Variations in the order of 50%, 100%, 200% and much more, are no longer unknown. Variations of that order simply cannot be accommodated in a general percentage addition...
> ...Secondly, the scale of percentage additions has already grown. It is far from unusual to find additions of 20-30% in Australia. These are significant sums. Clients, not

unreasonably, are beginning to demand substantiation of such additions. The high percentages figures may in fact be justifiable, but any justification first requires an analysis of the uncertainty".

1.2 THE PROBLEM

Two of the requirements of the client, as well as the design team, is to be informed on the financial price for the intended project, and to made aware of other feasible design solutions provided by the team (Ferry and Brandon, 1991) as they develop through the different stages of design. These duties normally rest with the quantity surveyor, who uses various price forecasting modelling methods to achieve these objectives.

It is usually found that the professional team has insufficient time to investigate the enormous number of potentially feasible design solutions (Ferry and Brandon, 1991). As the architect works on the clients brief, he provides the quantity surveyor with sketch drawings, design details and working drawings, who in turn uses one of the models available to him to draw up his forecast and cost plan.

A further problem lies in the fact that the architect can commit up to 80% of the total cost of the contract before completion of his sketch drawings (Kelly, 1987; Cattell, 1986; Hardcastle *et al.*, 1987). It is therefore important that the quantity surveyor liaise with the architect and design team as early as possible to be in a position to provide any cost related information. Failure to do this may result in financial losses as it is difficult to make any changes to the overall design at a later stage of design.

The concept of uncertainty is not unique to the building industry, but a characteristic of the whole human condition (Toakley, 1989). In looking at the concept of uncertainty, Reece (1979) contends that uncertainty represents insecurity, a loss of confidence in the external world and consequently unhappiness. Reece (1979) goes on to say that for an individual to be psychologically satisfied, he must be certain and confident in the consistency and reliability of the world around him. The construction industry presents a number of uncertain situations and, although classified as a science, there are no physical laws, or combination of laws, that enable someone in the building industry to provide an absolutely detailed forecast of the development and outcome of any particular situation (Gallie, 1957). It is therefore assumed that the need for certainty in cost related areas within the construction industry would be of great psychological benefit to the entire design team.

One of the characteristics of a perfect market condition is that there is perfect knowledge of the prices and quantities sold in all transactions, implying that the prices of goods would have to be known before they were sold. In the construction industry, the price of construction projects are usually agreed in principle before the construction process begins (Raftery, 1990), but because of the 'one-off' nature of a building project, the pricing of each building project is a unique process that has to deal with a variety of uncertainties. It is therefore difficult to determine the price of a commodity that is so diverse as that of a building. Hence, the use of modelling techniques that simulate or model previously known information in these imperfect markets is essential. However, one of the major shortcomings of existing price modelling methodologies is that they fail to address the data/design/model/output interface, presented by Raftery (1990), with respect to uncertainty. The difficulty arises in choosing an appropriate forecasting model based on the information available at that stage of design.

Erwin *et al.* (1991) refer to the building procurement process as a special kind of intelligent decision-making process, in which the presence of uncertainty may prevent a good, or result in a bad decision being made. This statement is supported by Bradshaw (1987) who states that a decision making process may be sub-optimal if it doesn't have the ability to handle both the uncertainty that the users have about their inputs, and that which experts have about their particular knowledge domain. Marshall (1988) adds that if better decisions are the result of more complete and certain information, then accounting for uncertainty will enhance decision making. The existence of uncertainty within the design process of the construction industry, coupled with the inability of traditional cost models to provide for the treatment of uncertainty (Erwin *et al.*, 1991) needs to be identified, analysed and accepted by practitioners, for optimal real-life decisions to be made.

1.2.1 SPECIFIC SUB-PROBLEMS TO BE STUDIED

Traditional methods of price forecasting have a limited ability to handle the uncertainty emanating from the building procurement process. In order to improve the practitioners forecasting abilities with relation to uncertainty, the factors which influence the forecast need to be ascertained. In this study areas which cause or lead to uncertainty will be analysed. These areas include;

> The uncertainty in the communication of information and ideas, as well as the different perceptions, that the members of the design team may have.
>
> The uncertainty in the rates, extracted from various data sources, used by the quantity surveyor to compile a forecast.
>
> The uncertainty that results from the unavailability, or lack of information during the required stages of design.

The inappropriate matching, or complete lack of uncertainty techniques in the different cost models, at various stages of the design process.

1.3 THE HYPOTHESIS

By analysing the nature, extent and techniques of handling uncertainty within traditional price models, it can be shown that an expert system environment could incorporate, evaluate and communicate uncertainty from the inception to tender stage of a project.

1.4 OBJECTIVES

The objectives of this research report are as follows;

To list the areas in which uncertainty becomes manifest during the various stages of the design process.

To show that practitioners do not take adequate steps with regards to the treatment and incorporating of uncertainty in the traditional pricing models.

To show that expert systems can be used as a modelling environment to incorporate, evaluate and communicate uncertainty, from the inception to tender stages of a project.

1.5 THE METHODOLOGY

The steps undertaken for this research include;

1. Literature review
2. Survey questionnaire
3. Interviews
4. Analysis of surveys and interviews

1.6 LIMITATIONS

Because uncertainty is evident in the entire building process, an exhaustive study of the whole subject would take too long. For the purpose of this study, uncertainty will only be dealt with in the design process from the inception stage of a project to the issuing of tenders.

It is assumed that the contractor will enter the design process after the tender stage. It therefore follows that any areas of uncertainty relating to the contractor will not be dealt with in this report.

1.7 STATEMENT OF ASSUMPTIONS

According to Bowen and Edwards (1985), the term 'price' must take market considerations into account, and hence the profit of the contractor must also be included. In this report, the term price is preferred to that of cost, as it relates to the financial figure that the client will be paying for the project.

'Forecasting' as opposed to estimating is not only a prediction of an uncertain future event (Bowen and Edwards, 1985), but in addition, it should also be quantitative, qualitative, time related, and probabilistic in nature (Jones and Twiss, 1978).

In the construction industry, the terms 'risk' and 'uncertainty' are often used interchangeably. Hillebrandt (1974) states the occurrence of some events may move the category of risk to that of uncertainty as new or better information is made available. Although there is no exact definition of the two terms, for the purpose of clarity in this report, the distinction between these two terms given by Knight (1921) will be adopted. Knight (1921) states that risk arises when the assessment of the probability of a certain event is statistically possible, and is therefore insurable. On the other hand, uncertainty arises when the probability of the occurrence or nonoccurrence of an event is indeterminate, making uncertainty not insurable.

CHAPTER 2

THE NATURE OF UNCERTAINTY IN THE BUILDING DESIGN PROCESS

2.1 INTRODUCTION

As this study deals with the treatment of uncertainty in price forecasting, it is not the intention to deal with the uncertainty that exists outside the building industry, as uncertainty is not restricted to the boundaries of the building process, but the world at large. However, as an introduction to the uncertainty present in price forecasting, it is appropriate to look at the building process in general to see why uncertainty is so prevalent in the industry.

The existence of uncertainty is not a new concept. Higgin and Jessop (1965) identified the two major characteristics of the building process as 'independence' and 'uncertainty', with Toakley (1989) stating that uncertainty exists as a result of an absence in information. Toakley (1989) states two factors for this uncertainty or lack of information as arising from either "vagueness in the identity of variables (or factors) that explicitly define a system or randomness or a lack of knowledge of values of the variables which describe the system" (Toakley, 1989, p.7).

The building industry functions on the co-operative interaction of different specialists working together with goal of producing a building acceptable to the client who commissioned the initial work. These specialists, each with their own set of 'values' have become immune to working in an industry riddled with uncertainty. However, according to Higgin and Jessop (1965), this atmosphere of uncertainty among the design team provides an environment for conflict. Higgin and Jessop (1965) list four areas where this conflict of interaction among the design team can result in uncertainty. These four areas are listed below.

1. client about members of the design team and *vice versa*;
2. design team about each other;
3. client and design team about members of the construction team and *vice versa*;
4. members of the construction team about each other.

The rest of this chapter is devoted to providing a classification of some of the uncertainties present in price forecasting models during the design stages of a construction project, as well as going into more detail about these uncertainties.

2.2 UNCERTAINTY INHERENT IN IMPERFECT INFORMATION

The success of any project price forecast stems from the true and accurate transfer of information and ideas between the client and the design team. However, problems can become manifest when the presence of uncertainty is detected within the communication process. This can be partly attributable to the imperfect knowledge available to the design team members in the early stages of a project, as well as the different perceptions held by individual design team members. This, in turn, impacts on the provision of the design-to-cost advice offered by the building economist.

In the communication process, the sender of a message knows what he wants to say. The problem (relevant to price forecasting) arises in the transmittal of those ideas and perceptions to a person who will receive the message in the way that it was intended, with feedback being one of the mechanisms to determine the degree shared meaning achieved by the exchange. Interference is the result of some 'noise' acting on one of the variables of the communication equation. This 'noise' can cause a form of uncertainty that can lead to problems in communication. One of these problems, combined with the fact that little is known about the nature and effect of uncertainty in the building procurement process, leads to some concepts not being communicated effectively between the design team members.

The objective of this section is twofold. Firstly, the conveyance of ideas and perceptions between members of the design team will be discussed with the view to analyzing the problem of uncertainty in communication. Secondly, the way that communication incorporating uncertainty is conveyed to the design team by the quantity surveyor, architect and client will be assessed.

2.2.1 THE TRANSFER OF INFORMATION

The transfer of information within the building procurement process is evident from the start of the inception stage. To state a hypothetical case, a prospective client may realise a need or desire for additional office space. The client's next logical step would be to convey those needs and/or desires to an architect in the form of a brief. The architect, acting as the clients principal agent, would then appoint a design team (assuming that the size of the project warrants it) to work together by sharing their expert knowledge in a particular field. By continuing in this way, the design team should produce a proposal that would be to the satisfaction of the client.

The transferal and receiving of information between the different parties involved might take on different forms, for example, it may be verbal, written or verbal with a written explanation. This transferal and receiving of information, or communication is thus essential for the effective and efficient completion of the project. If, for some reason, the information given in the brief by the client was vague or distorted, it could result in an incomplete message reaching the architect. The architect (or receiver) may then weigh the evidence in the light of all past knowledge he possesses to make a decision (this decision being the 'best guess' about the transmitted message). The decision, which may be made upon the 'limited evidence' could result in a incorrect alternative being taken.

It is not within the scope of this dissertation to critically evaluate the entire communication process *per se*, but rather look at one aspect of the process, that being the communication of information. However, before any discussion of the uncertainty that could be apparent in this transfer of information can take place, it is necessary to define the communication process and mention some of the problems that can be the cause of uncertainty of some form.

According to Berlo (1977b), the concept of information has to do with the patterning of discriminable units of matter-energy, with a constant perceived as not having a pattern (a constant can therefore be associated with data). Given the possibility of the occurrence of two or more patterns, there will be uncertainty as to which pattern will occur.

In 1949, Shannon and Weaver introduced a model of information processing (see Fig. 2.1). The model was developed to measure the correspondence of speech patterns over distance, while in communication over the telephone system. Their model was only concerned with the fidelity of information (a correspondence in pattern between input and output), and not the reference of information (Berlo, 1977a).

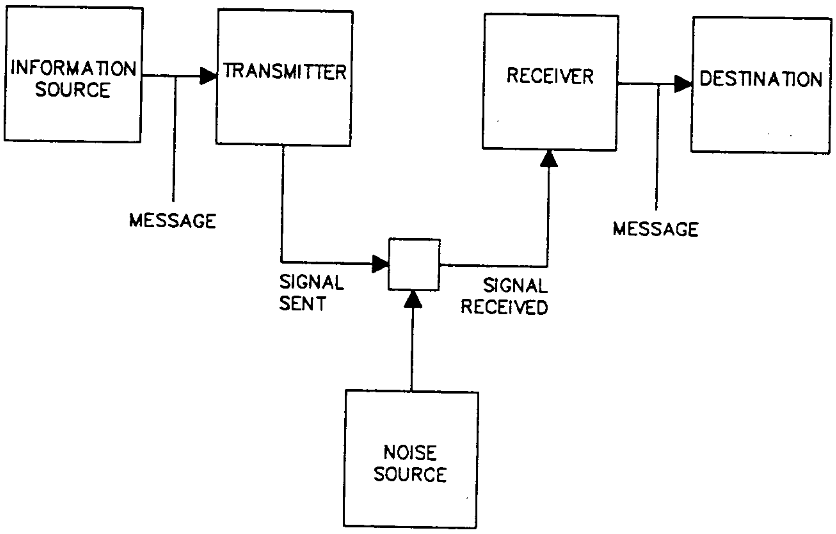

Fig. 2.1 Model of information transfer (after Shannon and Weaver, 1949)

In the above model, information in the form of a message (be it verbal, written, etc.) is transferred from the sender with the intention that the initial 'pattern' reaches the receiver unaltered (*ie.* with complete clarity and certainty). The amount of interference, or 'noise' within the channels or media which are used to convey the message is one of the causes of uncertainty in information transferal within the communication process (Cherry, 1978).

Tubbs and Moss (1980) define interference as anything that distorts the information transmitted to the receiver or distracts him or her from receiving it. The interference, which could take the form of anything from a sound distraction to a smoke filled room, leads to an increase in the receiver's doubt.

Tubbs and Moss (1980) offer two classifications of interference; technical interference and semantic interference. Technical interference refers to the factors that cause the receiver to perceive distortion in the intended information or stimuli. For example, a person with a speech impediment may find difficulty in making words clear to someone, or the blast of a nearby radio may hinder someone hearing what is said.

Semantic interference occurs when the receiver does not attribute the same meaning to the signal that the sender does. For example, at the inception stage of a project, the client may ask the quantity surveyor for the estimated cost of the building (in this case, the clients perception of cost is the total amount that he is going to pay at the end of the project). The quantity surveyor **may** interpret 'cost' as being the final total of the project, less the contractors profit.

2.2.2 THE COMMUNICATION OF UNCERTAINTY WITHIN PRICE MODELLING

It has become increasingly evident that, with the passing of time, client's needs for greater financial surety have placed pressure on quantity surveyors to produce more accurate forecasts along with an indication of the certainty of that forecast (Hodgetts, 1987).

According to Bowen (1992), the participants in the communication of price forecasts are the building economist and the users of the forecast, namely the client and the architect. For any information to be effectively transmitted between these parties, the information must be transmitted (and received) in a manner meaningful to all parties (Bowen, 1992). In order for the users to have a complete understanding of the forecast, they must be made aware of the uncertainty that may be present in the forecast. When communicating any uncertainty that may be associated with a forecast, the converses inevitably have different amounts of knowledge and experience about the topic under discussion (Isaacs and Clark, 1987), necessitating a continual appeal to their common ground - their mutual knowledge, beliefs, and assumptions (Stalnaker, 1978; Clark, 1985).

2.3 THE UNCERTAINTY IN PRICE FORECASTING DATA

According to Raftery (1981), a forecast will have at least the same uncertainty as that pertaining to the data on which it was based. In this section, the 'data' which are used to produce the forecast will be dealt under four separate sections, each of which having an element of uncertainty attached to it. Although kept separate for the purpose of presentation, it is noted that these four factors do have an influence over each other.

Firstly, the need for and use of data is compared to the forms of data available to the forecaster. Secondly, the degree of accuracy of price and cost data used in forecasts is examined. The third, section deals with the variability of the rates that the quantity surveyor uses in trying to predict the rates that the contractor will insert in the tender document. The fourth and final factor deals with the design/data/model interface in respect of uncertainty.

2.3.1 THE NEED AND USE OF PRICE DATA

If the definition of 'price' given by Bowen and Edwards (1985) is used, then the term 'price data' can be defined as a collection of information which has taken market considerations into account, (eg. a fully priced bill of quantities from a previous project). By using this price data, the quantity surveyor could assess the market conditions at the time of tender, make any adjustment deemed necessary to his base estimate, and use the rates or information obtained from a bill analysis to produce the new forecast. It is not always possible to use data that falls into the above category, as price data obtained from bills is both subjective and inaccurate as will be shown later in this chapter. It is therefore necessary for the forecaster to use all the possible data at his disposal to make a forecast.

Because buildings are measured in terms of quantities of number, areas, volumes and items, it is necessary to resort to the use of historic cost data to put financial amounts next to these quantities. There are two main sources of data available to the forecaster; these being 'in-house' and 'published price data' (Morrison and Stevens, 1980). Table 2.1 represents the forms of data that are available to the forecaster.

Table 2.1. Sources of historic data

IN-HOUSE DATA	PUBLISHED DATA
Elemental analysis	Price books (eg. Merkels)
Priced bill of quantities	Journals (locally available) - Professional builder - Quantum
	Government literature - B.E.R. - Building cost index - Haylett - Building plans passed and building plans completed

Most practitioners prefer using the first alternative (Morrison and Stevens, 1980) as they have some familiarity with the circumstances surrounding the rates. In-house data has obvious advantages over published data for a number of reasons. Firstly, because the practitioner is familiar with the data, he is able to prepare the forecast quicker, especially if the source referred to is his own. Secondly, no assumptions will need to be made as he is able to get a greater degree of detail from the past records, if required. Thirdly, having been involved with a similar project in the past, he will be able to spot errors more quickly. Fourthly, and most importantly, he is familiar with the circumstances that led to the build up of the rates, placing him in a better position to make any adjustments if deemed necessary.

Bowen and Edwards (1985) state that the existence of traditional price forecasting techniques used to model design are dependent for their operation upon data derived from historical sources, which, according to them, is used and given without explicit qualification of their inherent variability and uncertainty. This assertion is supported by Mathur (1982) and Beeston (1975), who both believe that, when using historic data, one can not set a 'single figure' cost limit for a building. The reason given by Mathur (1982) and Beeston (1975) is that there are to many variables that can play an influencing role in the determination of the 'single figure'. Using previous data can also be misleading because of the fluctuation or variability in cost, from one project to another. Published data should be used as a confirmation of the practitioners work, or as a last resort if no in-house data is available. If published data is used, Ashworth (1980) believes that one must consider the reliability of the price information used, and for the data to be used efficiently, it is important that the results provide an accurate representation of the eventual values.

2.3.2 THE ACCURACY OF DATA

According to Ashworth and Skitmore (1982), price forecasting is said to be largely affected by the amount of data available at the time the forecast is made. Barnes (1974) depicted this concept in the form of a graph, shown below.

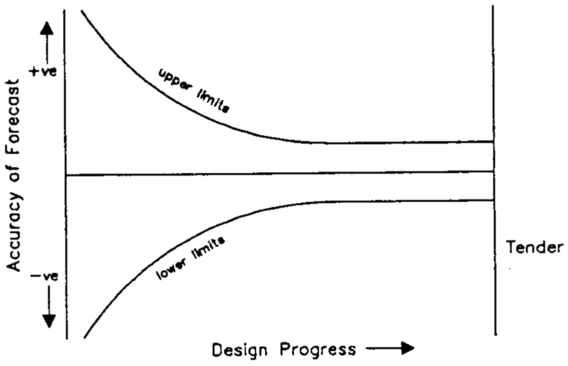

Fig. 2.2 Forecasting error over time/information release (after Barnes, 1974)

Reference to the above figure suggests that the accuracy of a forecast improves with time, as more information becomes available. At this point, three conclusions provided by Ashworth and Skitmore (1982) are worth noting. Firstly, the level of accuracy improved slightly from the early design stage to immediately prior to receiving tenders. Secondly, the lack of information in the early design stages has little effect on forecasting accuracy. Lastly, the absence of a more reliable data collection method tends to preclude a more confident prediction, which gives rise to the fact that a forecast will have at least the same uncertainty as that pertaining to the data on which it was based (Raftery, 1981).

Because of influencing factors such as the availability of design information, the type of index used, the number of bidders, market conditions, personal factors influencing the forecaster (Ashworth and Skitmore, 1982), unknown features of the site, inflation costs not allowed for, and unforeseen construction difficulties (Beeston, 1986), forecasting cannot be regarded as the exact science (Flanagan and Norman, 1983), and hence no one model exists that can exactly forecast the price of a project. Likewise, because of these influencing factors, a percentage accuracy, or error, is difficult to determine. The determination of accuracy is made more difficult because of the different perceptions the quantity surveyor, architect, client and contractor have with reference to the final accuracy of a project.

Clark and Lorenzoni (1985) mention three factors that could impact on a forecasts accuracy;

1. Time in the life cycle
2. The cost engineer, or forecaster
3. The methods and tools available

Clark and Lorenzoni (1985) summarize the above points by stating that the forecast accuracy is a function of the time the forecast is prepared, in relation to the project life cycle. It is also affected more by variations in the basis than in the forecasting methods of the quantity surveyor. The third point refers to the accuracy as a function of the company experience to it's approach in the project execution.

It has been argued by many (Brandon, 1985; Drake, 1984) that a large computer database can lead to a more accurate forecast. This data base could include 'price', 'cost' or both 'price and cost' data to make its analysis capabilities more powerful. The advantages of a large database are as follows (Brandon, 1985):

1. It will be possible to update data more accurately and efficiently.
2. It would be able to store and make information available to a greater number of users.

3. It will be possible to obtain specific needs in seconds.
4. It would be possible to build up regression models, ie. show the relationships between two variables.

Bennet (1987), among others, believes that the future of accurate forecasting lies in the need for a computer work station, linked to a central database. This would give the quantity surveyor a better understanding of the contractors construction costs, as well as allowing a more accurate matching of new projects with those in the database.

Data transformation

A further aspect, and a major cause of data inaccuracy is the way in which the original price data was collected. Raftery (1984a) states that subjectivity creeps into data in two ways. Firstly, during the recording of the event, and secondly, during subsequent transformations of the data to produce 'information' for various procedural requirements. It is not within the scope of this research to deal with this in great depth, but surfice it to say that two major transformations occur. The first is when the sum of the resource costs is spread over the unit rates used in the bill of quantities. The second is when the unit rates are subdivided and clustered into element costs. This process is summarised in Fig. 2.3.

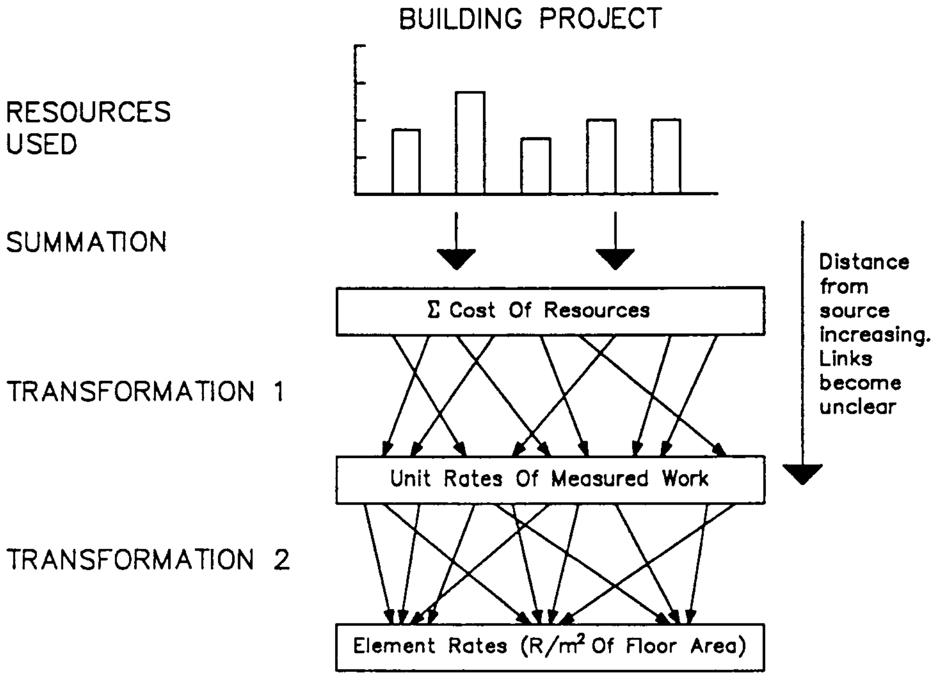

Fig. 2.3 Data transformations (after Raftery, 1984a)

One of the criteria of performance for a model to be effective, is that of data reliability and accuracy (Raftery, 1984a). Raftery (1984a) states that decisions are made in the light of information available at the time the decision is made. The data transformation period should be objective, as the data used is incompatible with the generation of cost or price, because of the subjectivity involved in 'playing' around with the figures at the tender stage, and the variability of the data. Raftery (1984a) states further that the rates the forecaster uses are a mere notional breakdown, as he is trying to judge what figures the contractor is going to use.

2.3.3 THE VARIABILITY IN THE DATA USED BY QUANTITY SURVEYORS

Variability of price data

Beeston (1983) and Ashworth (1983) both support the premise that due to a lack of research into building price data, progress in price forecasting has been stunted because of the validity of price data being uncertain. One of the influencing factors of data accuracy is data variability, with Bennet and Ormerod (1984) defining variability as the range and frequency distribution of possible outcomes in the execution of a particular task. The variability in price data may be the result of known or unknown causes, with a disappointing amount of unexplained variability existing in the unknown causes (Beeston, 1983).

In determining the price of a project, the quantity surveyor makes use of one or more forecasting techniques to model the project in question. These models, when broken down and analysed, all rely on the pricing of information. The result is a rate that, either on its own, or in combination with others, will be the figure the quantity surveyor uses as the basis for his forecast. This rate is determined by the quantity surveyor in one of two ways. Either by first principles, or by reference to a 'library' of rates determined from 'historic sources', which he updates and adjusts to take the prevailing market conditions into account. The first option of working out the rate by first principles is more accurate, as it would be calculated from information and data relevant to the project for which the forecast is being done. However, a major problem in calculating from first principles is that the quantity requires a lot of information that is often not available to him at the time requested. This option also requires a lot of time for calculation, of which he usually has little.

The second method is to use 'in-house' data. This method also has its problems, for example, by using previously priced bills as the source of data, all the uncertainty associated with its build up are transferred into the new project.

According to Flanagan and Norman (1983), cited by Valenti (1986), "the principle weakness of using any form of unit price rate approach in estimating, is that it neither recognises nor deals rigorously with the fundamental problems caused by price variability". This is supported by Raftery (1981), who questions the validity of historic data, and argues that being an average, or family of figures, the data has a level of uncertainty attached to it. This is mainly due to the variability of the rates which are subjectively updated to take the prevailing market conditions into account.

Variability of bill of quantity rates

It is Ashworth's (1983) belief that, on average, tenders may vary by as little as 10%, but the individual trades may vary by 40-50%, and the items making up the trades by as much as 20%. Beeston (1975) showed some of the co-efficient of variation from bill to bill for the same selected items in various trades. However, to determine this accuracy or variability of price rates, the user needs to analyse 20 to 30 projects of the same nature to get a representative average (Beeston, 1975). These figures (shown in Table 2.2) represent the average for several items in the specified trade sections.

Table 2.2 Co-efficient of variation for selected items in various trades (after Beeston, 1975)

TRADE	CO-EFFICIENT OF VARIATION
Excavator	45 %
Carpenter	31 %
Drainlayer	29 %
Joiner	28 %
Bricklayer	26 %
Roofer	24 %
Plumber	23 %
Painter	22 %
Steelworker	19 %
Concretor	15 %
Glazier	13 %
All trades	22 %

What is important to note from the above table is that rates can be classified into broad categories of reliability. Reliability of data may be expressed by the consistency which they exhibit when many prices are obtained relating to the same item description. This point is supported by Raftery (1981) insofar as he states that data users must be aware of both the reliability and the variability of the data used in producing forecasts. Marston (1985) says that within individual bills, elements have dependencies with other elements because of the special circumstances that surround that particular project. This would mean that one could not use rates from different projects and expect the same resultant accuracy.

As an example of the uncertainty associated with rate variability, rates from ten quantity surveying firms in the Western Cape have been collected for eight different bill items. The variability of these are indicated in Table 2.3 and Table 2.4. These rates were obtained from the Bureau of Economic Research, as quantity surveying practices were not co-operative in parting with the information.

Table 2.3 give the rates that ten quantity surveying offices supplied to the B.E.R.. As the monthly response from quantity surveying offices is very low, rates for two consecutive months had to be used. The August 1990 rates have been adjusted to suit those of July 1990 by means of indices supplied by Medium Term Forecasting. Although the rates are not considered ideal for analysis, they do illustrate the point of variability between rates used for the same bill item. A statistical analysis of the rates depicted in Table 2.3, are presented in Table 2.4. From Table 2.4, it is seen that the co-efficient of variation (the measure of variability) can be as high as 50% for the same bill item. This variability amplifies the presence of uncertainty in the choice of bill prices used by quantity surveying firms.

Table 2.3 Variability of rates used by firms

	July 1990							August 1990 rates adjusted to July 1990		
FIRM	1	2	3	4	5	6	7	8	9	10
Excavate for footings	20.57	23.66	8.97	8.40	16.38	22.77	7.00	27.79	41.54	18.57
Mass concrete in footings	183.06	228.36	178.50	161.24	201.40	144.28	160.00	286.46	233.15	210.65
Reinforced concrete	182.06	223.73	184.85	205.76	243.06	154.64	----	289.23	265.57	224.48
Half-brick wall	31.71	40.68	----	35.36	32.83	51.69	31.50	43.66	37.21	37.99
One brick wall	64.31	77.97	----	70.73	67.38	88.24	62.00	85.40	69.65	65.64
25mm Cement screed	11.07	11.67	10.93	9.89	11.10	----	8.00	11.87	15.82	11.75
Internal plaster	11.46	11.60	----	9.64	10.99	----	9.00	12.44	9.30	8.06
3 Coats P.V.A.	7.28	7.50	6.20	----	8.12	----	4.50	7.27	7.86	8.21

Table 2.4 Statistical analysis of the variability in rates

	Minimum	Maximum	Mean	Standard deviation	Coefficient of Variation
Excavate for footings	7.00	41.54	19.57	10.46	53.45 %
Mass concrete in footings	144.28	286.46	198.71	42.73	21.50 %
Reinforced concrete	154.64	289.23	219.26	42.69	19.47 %
Half-brick wall	31.50	51.69	38.07	6.55	17.21 %
One brick wall	62.00	88.24	72.37	9.39	12.97 %
25mm Cement screed	8.00	15.82	11.34	2.07	18.25 %
Internal plaster	8.06	12.44	10.31	1.52	14.74 %
3 Coats P.V.A.	4.50	8.21	7.12	1.23	17.28 %

Indices as a means of updating rates

As time is often a critical factor in the preparation of a forecast, it is not always possible to obtain the prices of all items at the time the forecast is prepared and hence the use of indices to update 'historic' data. In order to improve and refine techniques of price forecasting, greater use has been made of indices which update 'stored rates', as well as the entire forecast (Wright and Hodgetts, 1980; Brook, 1985). The aim of an index is to measure the change in the price or cost in an item from one point in time to another in relation to some base date (Bathurst and Butler, 1973; Ferry and Brandon, 1991).

The difference between a cost and price index needs clarification, as the two indicators have given rise to various misconceptions and uncertainties pertaining to their use in the past (Brook, 1985). The cost index (eg. Indices supplied by the Bureau of Economic Research) reflect changes in labour productivity, the availability of labour and materials, as well as taking tender competition into account (Brook, 1985), whereas price indices (eg. the Haylett Indices) reflect the actual cost to the contractor.

Ferry and Brandon (1991) list a number of purposes for which indices can be used, but for the purpose of the subject under discussion, it is only necessary to mention three. Firstly, the use of the B.E.R index as a means of updating individual 'historic' rates. Secondly, the B.E.R index can be used as a means of updating the entire forecast to a future point in time. Lastly, the Haylett Index can be used as a means of updating the forecast from the tender date to the final completion date (see Fig. 2.4).

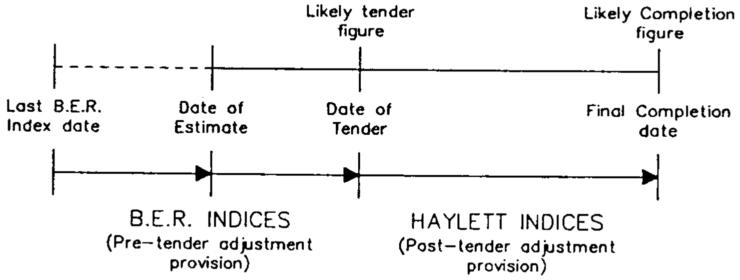

Fig. 2.4 Graphic representation of indices used in forecasting

A major problem associated with the use of the B.E.R. Index as a means of updating individual rates is that, being a weighted statistical average representing an entire project, identical bill items for different functional types of building are updated in the same way. For example, the rate of a one brick wall in a small residential building is updated by the same index as that for a one brick wall constructed in a large commercial development, even though the labour productivity utilised in the two buildings may be completely different.

2.3.4 THE UNCERTAINTY IN THE DESIGN/DATA/MODEL INTERFACE

Although essential to price modelling, data is the cause of much uncertainty within price forecasting. Its accuracy and suitability at the various stages of design needs to be greatly enhanced if the future of price forecasting is to be improved.

The purpose of a model, according to Shore (1978), is to solve a specific problem by incorporating some (but not all) of the elements from their real-world system and specify the relationship between these elements in an explicit way. Ferry and Brandon (1991) offer three principles in regards to cost modelling in the building industry. Firstly, the model utilised should suit the stage of design. Secondly, the data must be compatible with the model at the stage when it is implemented. Lastly, the model should cope with design constraints and be able to test the feasibility of a proposed solution. The variability that already exists in the data (mentioned earlier), together with the fact that models do not incorporate all the elements of the real-world system (Shore, 1978) results in a situation of uncertainty.

Ferry and Brandon (1991) state that a model can only provide accurate forecasts if the information utilised is reliable, with decisions being made in the light of the information available at that time. Ferry and Brandon (1991) state that one of the major problems with modelling is the need to ensure that the data are reliable, as well as relevant for all conditions of use of that model.

When considering the performance of data in relation to the design/data/model interface, it is appropriate to look at the model presented by Raftery (1984b) and represented in Fig. 2.5. Raftery (1984b) suggested that new price models be designed which would be more applicable to the data at the different design stages of the project.

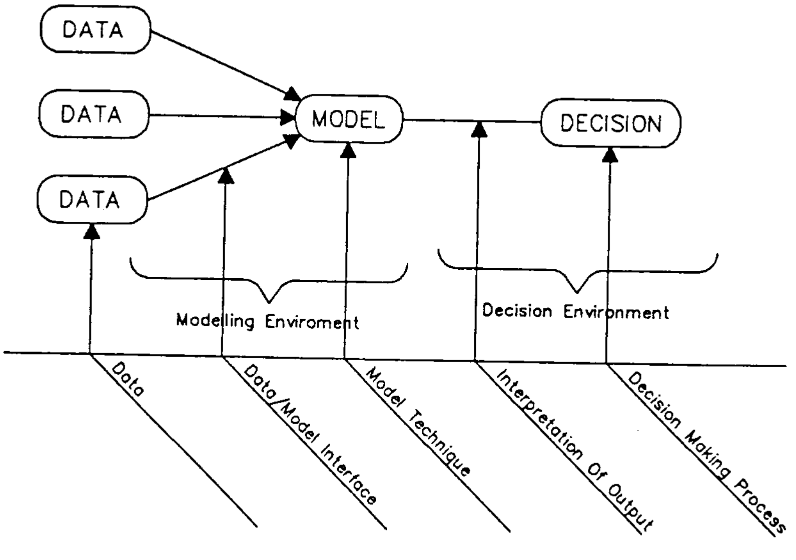

Fig. 2.5 The decision and modelling environment (after Raftery 1984b)

Raftery (1984b) believes that the degree of development in the design stage should constitute the basis for choosing a model, for the amount of information increases as the project time increases. This results in the forecaster trying to match the model type to the amount of information available (Morrison, 1984). Ferry and Brandon (1991) illustrate this fact in the form of a pyramid.

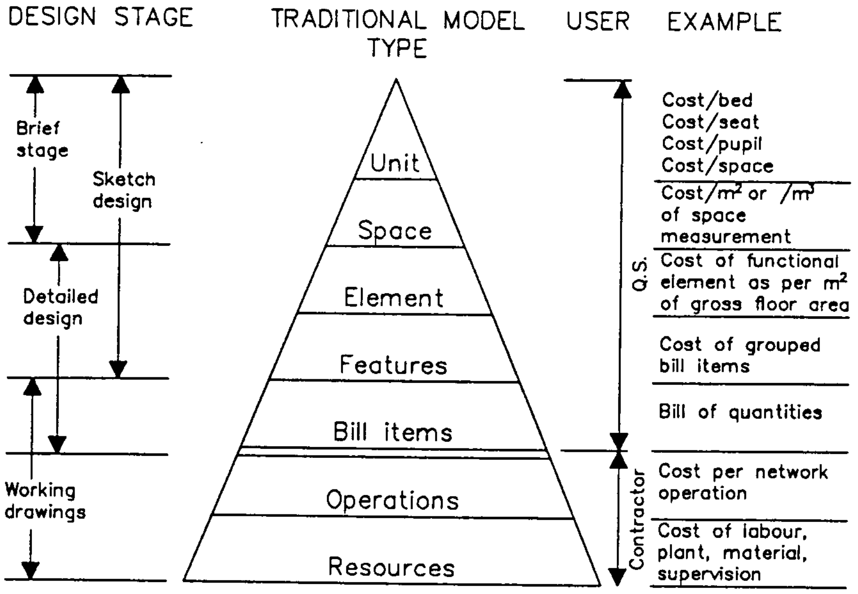

Fig. 2.6 The pyramid of traditional cost models (after Ferry and Brandon, 1991)

Gilmour and Skitmore (1989) question this model with regards to the demarcation between methods and the decision of when to make the change. The techniques are also not likely to be compatible, resulting in a new process starting with each change of stage of design. Gilmour and Skitmore (1989) believe that a single estimating system should be used for the entire sketch design stage, as indicated in Fig. 2.7.

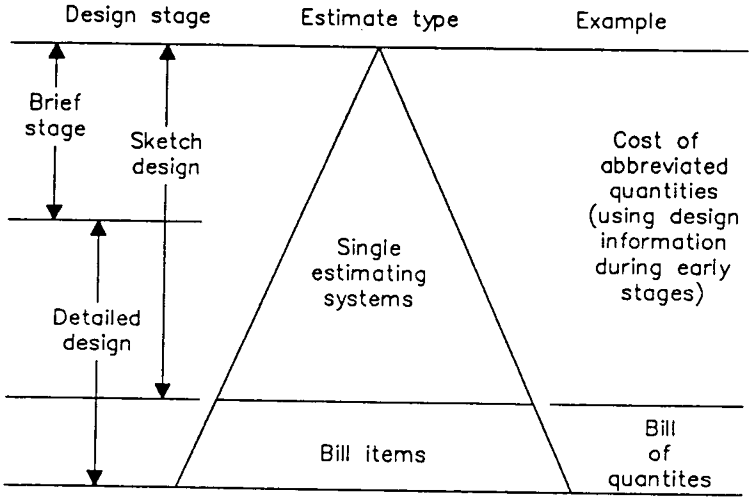

Fig. 2.7 New early stage estimating system (after Gilmour and Skitmore, 1989)

As one moves down the pyramid presented by Raftery (1984b), and more information becomes available, a more accurate model is utilized. However, a major problem with this notion is that as the amount of information increases in quantity and quality, the model used makes no mention of where the previous model failed, ie. another more sophisticated model is being used without any reference being made to the output of the previous model.

Different models perform better than others in respect of the data/model interface (Raftery, 1987). In proving this, Raftery (1987) uses three different models, namely, an element-based floor-area model, a regression model and a probabilistic model, to which he applies two important questions. The first question relates to the appropriateness of available data at the design stage for that of the model.

The second question determines whether it should be necessary to establish if the data is at a higher detailed level than the model. Raftery (1984b) continues by stating, if that were the case, then efforts should be directed towards refining the techniques of modelling in maximizing the gain from the existing data. If the data were at a coarser level of detail than the relatively larger problem of improving the recorded data should be addressed.

More optimistically, Brandon and Newton (1986) believe that computers capable of holding large data bases will be the answer to the development of building cost and price forecasting methods.

2.4 CLASSIFICATION OF THE TYPES OF UNCERTAINTY

Until fairly recently, the provision of uncertainty within cost modelling has usually been described by practitioners in phrases such as 'the preliminary nature of the budget' or 'indicative appraisal only' or 'contingency allowance' (Hawkins and Soloman, 1989).

Uncertainty can become manifest in an indeterminable number of forms (Fox, 1986) but, to date, no techniques exist that are able to handle all forms of uncertainty (Mamdani *et al*, 1985; Toakley, 1989). It is therefore necessary to evaluate and draw characteristics from some of the methods used to deal with uncertainty so that the 'best' solution can be found to handle the different circumstances that presented themselves to us (Scott *et al.*, 1988).

Many authors (eg. Buchanan, 1982; Tong, 1982; Klir, 1987; Allwood, 1989; Wernerfelt and Karnani, 1987; Scott *et al.*, 1988; Erwin *et al.*, 1991 and Ng and Abramson, 1990) have provided classifications of the various types of uncertainty. The works of Wernerfelt and Karnani (1987), Scott *et al.*, (1988) and Erwin *et al.*, (1991) are worthy of further note.

Wernerfelt and Karnani (1987) gives four classifications of uncertainty which can be related to the macro environment of the building industry. These four classifications are demand uncertainty, supply uncertainty, competitive uncertainty and externalities. Under demand uncertainty, they state that the size of the market, the size of the different market segments, the desired product and the appropriate distribution channels may be uncertain.

Supply uncertainty can arise from the internal structure or operations of the firm and, to a lesser extent in the building industry, from external developments in technology.

Wernerfelt and Karnani (1987) state that competitive uncertainty covers the nature of firms under conditions of competition. For example, the uncertainty that exists among contractors as to who will have the lowest tender figure to 'ensure' being awarded the contract. External factors of uncertainty may arise from social forces or the intervention of outside force, such as the government departments, planning authorities, public bodies and client organizations.

Scott *et al.* (1988), in their assessment of uncertainty in a property valuation context, also give four 'distinct' classifications that can be related to the building profession, namely, imperfect knowledge, intrinsic randomness, inherent indeterminacy and categorical uncertainty. Imperfect knowledge refers to a situation where the information needed for a particular task is not known, or is of uncertain nature. For example, a quantity surveyor, in performing a forecast may need to know the type of air-conditioning to be used in the building (Ashworth, 1988a) about which the user or architect may not be sure. Without the correct information the forecast can't be determined accurately.

Intrinsic randomness relates to a situation which is not yet known, but given its occurrence, will have a given probability affecting its outcome. As a result of the assumed premise, the probabilities would lead to the conclusion that the information was subject to uncertainty. For example (Erwin *et al.*, 1991), if a proposed building is to be, say three stories or higher, then the probability of that building being a concrete frame structure can be said to be 80%.

Inherent indeterminacy arises when more than one reason can be assigned to any one particular outcome. For example, an inaccurate forecast may be the result of poor or incorrect data, lack of experience on the part of the forecaster or a bad choice in the forecasting model. The sum of the probabilities that could be assigned to each of these causative factors would be unity as it is certain that the inaccurate forecast was caused by one of the mentioned factors.

Categorical uncertainty, which can be widely applicable in the building profession, describes a decision process in which the goals or constraints are 'fuzzy' in nature (Scott *et al.*, 1988). The term fuzzy being used to represent vague concepts such as 'soft' or 'hard' rock, where no crisp boundary to the definition of rock can be given (Bellman and Zadeh, 1970; Zadeh, 1979; Pang *et al.*, 1987).

The classification provided by Erwin *et al.* (1991), consider a more logical classification of uncertainty to be needed. They offer two classifications, namely uncertainty of outcome and uncertainty of explanation. Uncertainty of outcome refers to the uncertainty of the input variables in the decision making process, as they effect the final outcome of a situation, in a forward chaining of logic. For example, the choice of external finish of a certain quality will have a price consequence in respect of the finishes, the construction programme time, and the final rental achievable for that building (Erwin *et al.*, 1991).

Uncertainty of explanation refers to the backward-chaining of logic from the outcome of the process to the causative factors during the process. For example, if the cost of a project exceeds the clients budget, that uncertainty needs to be examined in a reverse process to determine the possible (with associated strengths of belief) causes of the cost exceeding the budget (Erwin *et al.*, 1991).

In considering an appropriate classification of the uncertainties inherent in price forecasting models, the classifications mentioned by Scott *et al.* (1988) and Erwin *et al.* (1991) are both applicable to the building process, and as such, will be adopted.

The following chapter is intended to display (a) how price forecasting models are influenced by the different types of uncertainty mentioned above and, (b) the ability of price models to cope with these uncertainties.

CHAPTER 3

METHODS OF MODELLING PRICE DURING DESIGN

3.1 INTRODUCTION

Unlike consumer products (for example, toys, stationary and electronic equipment) which can, and are easily replicated (even if to a small scale) to determine the cost of producing a range of that product, the same can't be said for a building, as it is a 'one-off' product. Ferry and Brandon (1991) state that the building of a prototype to test the functional and cost performance of a project as a whole would be 'impracticable as well as uneconomical'. To overcome this problem, one of the methods adopted by quantity surveyors to forecast the price on the building in *lieu* of a physical replication is to make use of mathematical or statistical cost models.

Authors such as Deutz (1952), Shore (1978) and others, give the purpose for the use of models as follows;

> Its ability to help organize data and provide a conceptual frame to talk about something.
>
> It serves to generate thinking and hypotheses about the system.
>
> It provides and leads to actual predictions about the way in which the system operates, thereby making pricing it possible.
>
> By providing 'sufficiently precise statements' about the structure and function of the system, it can dictate how to measure various states of the system.

In this chapter the writer discusses the more common methods of 'price modelling' used by practitioners and analyses their ability to handle uncertainty. The claims of Cyert and March (1963) and Hawkins and Soloman (1989) that firms try to avoid uncertainty rather than confront it, will then be addressed with reference to the practitioners forecasting methods. The aim is to provide a taxonomy for evaluating these models' ability to cope with the various forms of uncertainty, previously classified.

3.2 CLASSIFICATION OF FORECASTING MODELS

Classifications of the over 50 reported economic models (Newton, 1991a) have been presented in numerous ways by many authors (James, 1955; Ashworth and Skitemore, 1982; Raftery, 1984,1987; Wilson, 1987 and Newton, 1991a). For the purpose of this report, models will be grouped according to the classifications of James (1955) and Ferry and Brandon (1991), under the broad headings of 'traditional' and 'non-traditional' models. It is necessary to mention that this classification will be re-evaluated and possibly modified later, once the model's abilities to handle uncertainty has been presented. At this point it is envisaged that this new classification will be one into which models can be classified according to their ability to handle uncertainty.

Eight traditional methods of modelling will be analysed. These include; the functional unit, cubic, superficial area, storey enclosure, approximate quantities, elemental, bill of quantities and resource based methods. The two classes of non-traditional models evaluated are parametric estimates and regression analysis.

It is not the intention to discuss the detailed workings of each model as these have been covered extensively in publications by Seeley (1972), Smith (1986) and Cartlidge and Mehrtens (1982). However, a brief summary of the model along with their ability to handle uncertainty will be presented. The usage of these models by practitioners, along with their perceptions of the models ability to handle uncertainty is presented in Chapter Five.

3.3 TRADITIONAL FORECASTING MODELS

A] Single price models

As the name implies, single purpose models are aimed solely at the price for a project (James, 1955). James (1955) subdivided this group further under the headings of preliminary and later stage forecasts, with the preliminary forecasting models aimed at forecasting the broad financial feasibility of the project and the later stage forecasts providing a figure comparable with that of the lowest tender.

3.3.1 FUNCTIONAL UNIT METHOD

The objective of this method is to determine a rate for a given functional unit of a building, be it seats in a theater complex, beds in a hospital, desks in a school, or bays in a parking lot. The functional unit forecast is a simple method, taking into account the repetitive nature of accommodation when construction does not vary greatly. Its main advantage lies in its speed of calculation in establishing an overall target figure which serves as a useful tool for an early guide to decision making and budgeting.

Although often accepted as the final estimate, the functional unit method of forecasting is merely intended as a guide in the early stages of design. This models output can be misleading because a lack of precision during the comparison process can result in a variation of rates. The rates utilised by the model become obsolete in a relatively short period of time, resulting in errors which can give an incorrect final price figure. This usually necessitates the forecast being given in price ranges which would become more defined as additional detailed information is provided (Seeley, 1972; Smith, 1986). Although the mathematical process is simple, one of the main difficulties arise in the computation of the unit rate, extracted from the information of buildings of a similar nature (Seeley, 1972).

This method does not take the siteworks and foundation conditions of each project into account, with the consequence that they must be considered separately.

3.3.2 CUBIC METHOD

This method, adapted from the cost per square metre of building method, is based on the fact that a 'cube book' is kept by the quantity surveying office. The contents of the book include a price per cubic metre breakdown of the different functional components of a building, divided by the accepted tender price. The popularity of the method at that time led to a standard code of practice being drawn up, which set out rules for measurement. When a forecast for a new project was needed, an analysis of the cubic rates of previous projects of similar nature would be used as the basis for pricing the volume of the new project.

This method, used extensively between the wars, has faded in popularity and is now used primarily for the calculation of heating requirements for buildings, or for fire insurance premium estimates (Cartlidge and Mehretens, 1982). Although quick and simple to calculate, it is considered to be very inaccurate and unreliable, unless two identical buildings are used as comparisons, for no allowance is made for plan shape, storey height and number of stories or different construction techniques (for example foundation design).

The method does not serve as a useful information tool to the client and design team, as no mention is made of the usable floor area. Furthermore, any design changes put forward by the architect, are difficult to calculated quickly. A major shortcoming with this method is the quantity of variables used which can lead to compounding errors as the final sum is reached. These errors are highlighted by the variability in rates found in 'historic data'.

3.3.3 SUPERFICIAL METHOD

In this method, the floor area of the building is measured and multiplied by a rate per square metre. If the quality standards and specifications or constructional methods differ considerably within the building, they are measured separately with the appropriate rates being applied to each area (Seeley, 1972). This method is widely used by practitioners (Seeley, 1972). Its popularity may be ascribed to three main reasons. Firstly, the calculation is simple. Secondly, most forms of available data are recorded in this form, or alternatively, they can be easily calculated from existing or previous schemes. Lastly, and possibly as a result of the second reason, it is a meaningful concept of measurement to all parties involved in the design process.

The measurement is straight forward, but the accuracy of the forecast is dependant upon the rate, which is determined in two stages. Firstly, from an analysis of a past project and secondly, the updating and adjustment to suit present market conditions. As a result of the square metre rate being determined by the horizontal components of buildings, no direct account is taken of the vertical components, such as storey height, shape, construction, finishes, roofs or density of planning of the proposed project.

The method relates to the building only with no direct account being taken of the siteworks, services or vertical components of the building. A further problem arises if the project has a variety of different functions within the building (Ashworth, 1988), with the resultant need for a building of similar nature for comparison purposes.

Derived super method

Although similar in nature to the superficial method of estimating, the derived super method is usually used extensively as a 'screening estimate' and should not be mistaken with the superficial method.

The method is a rough way of price forecasting used primarily in the inception stage of the project to give the client or design team a rough idea of the probable price of the project. It makes use of a rate per square metre after determining the estimated required floor area for the building. The principle idea of the method lies in the fact that four basic areas that make up the total space of the required building, these being;

1. Usable space required by the client.
2. Ancillary accommodation, such as toilets etc. (these are often laid down in building regulations, and so are easily determined).
3. Access (corridor space, lobbies, etc.) expressed as a percentage of the usable space (usually between 10-25%).
4. The actual structure (this would depend on the building type, usually an allowance of between 5% and 10%, would be adequate).

3.3.4 STOREY ENCLOSURE METHOD

This method was introduced in 1954 with the aim of overcoming the problems associated with the above mentioned single-price rate models (Seeley, 1972). Although taking the shape, total height, storey height and total floor area of a building into account, it never gained wide acceptance and was quickly superseded by the elemental method of forecasting (Ferry and Brandon, 1991). However, it was said to be the stepping stone from single to multi-rate price forecasting systems.

The storey enclosure system relies on sections of a building being measured superficially and multiplied by a weighting factor which was determined by that sections effect on the total cost. These weighted quantities were then totalled and multiplied by a single rate obtained from the knowledge of previous projects, to arrive at an estimated total for the project. The total costs of piling, services, siteworks, curved works, etc. are added in the form of lump sums (Ridley, 1987).

B] Multi-rate price system

The single rate-price forecasts mentioned above do not analyse whether a particular design will meet its eventual cost. Multi-rate price systems meet this requirement to an extent and are defined by James (1955) as providing a price for the project, as well as "the various design-cost relationships between possible variants of the project" (James, 1955, p.215).

3.3.5 APPROXIMATE QUANTITIES

Approximate, or rough quantities is a measured combination or grouping of typical bill description items to form composite items (Ashworth, 1983). The major bill items measured are based on the principle that 80% of the final price is measured in 20% of bill items (Kelly, 1987; Brandon, 1984). The items not directly measured are usually taken into account by representing them as a percentage of the final account figure. Although this method takes the cost-variables of the building into consideration, no formal rules of measurement exist in order to achieve a structure of uniformity.

This method is regarded by quantity surveyors as being one of the most reliable methods of forecasting, provided that sufficient information is available at the time of implementation (Seeley, 1972). A possible reason for its popularity is that the measurement is handled in much the same way as a typical 'bill' measurement, with which the practitioner is very familiar. However, the method necessitates a large amount of information be available before the forecast can be produced. It is also necessary to consider details and specification at an early stage of design which may not yet be decided by the architect. It involves more work than the previous methods and therefore takes a long time to complete (Cartlidge and Mehrtens, 1982).

An added reason for its popularity with practitioners is that the updating of information at any stage of design is possible. However, due to a lack of rules or uniformity among forecasters in their way of measurement, if any items are overlooked at an early stage of the forecast, it is difficult to notice them later. The choice of which items to ignore and which to measure out in detail, as well as what percentage to allocate for sundry items to get a full representation of the project, is also very difficult.

3.3.6 ELEMENTAL ESTIMATING

This method, derived from the storey-enclosure method, analyses the cost of the project on an elemental basis (Ashworth, 1988). The method splits the building into a number of measurable components, or elements. These are then priced in one of two ways; either by the individual pricing of components, or by adjusting prices derived from a similar project handled in the past. The measurement, based on the document entitled "Guide to elemental cost analysis" (A.S.A.Q.S., 1982), is easily accomplished from the architects sketch drawings. This method takes into account any necessary quantity or quality alterations, as well making an allowance for the updating of information, and hence comparisons of cost implications are easily made (Cartlidge and Mehrtens, 1982).

This approach, along with the approximate quantities approach, needs a sufficient amount of information before any calculations can be done. It is not cost effective in small firms, as there is a difficulty in setting up a useful data base.

3.3.7 BILL OF QUANTITIES

Although only available at a late stage in the design process, the bill of quantities provides an indication of the final price in a single document. It is regarded as a product-based forecasting model because of its insistence on measuring the a project as 'finished work in place' (Ferry and Brandon, 1991).

Although regarded by some as not being a forecasting model, its main use (as a forecasting model) at this late stage of design would be to serve as a guide when analysing the individual rates of the accepted tender.

3.3.8 RESOURCE-BASED MODELS

In response to a call (Brandon, 1982) for a paradigm shift in cost modelling research, Bowen and Edwards (1985) and Bowen *et al.* (1987) were one of the first to take up this challenge and respond with a simulation based form of modelling. As defined by Ferry and Brandon (1991), resource-based models are 'concerned with the duration of construction, the resources employed, the sequence of events and the inter-relationship between activities'. It is the belief of Flanagan (1980) and Antill and Woodhead (1990) that any model incorporating operational information must provide a more reliable basis for price forecasting. However, one of the major assumptions of resource modelling is that the accuracy of the forecast is dependent on the availability of reliable data (Antill and Woodhead, 1990). Bennet (1978) adds that this form of price modelling would allow greater consideration to the cost implication of design alternatives.

In this form of modelling, the actual quantities measured will remain the same as those in a bill of quantities with the exception that the quantities would be allocated to the precise locations and operations in which they would be constructed. Hence, for this reason, the forecaster would need a detailed program of the project before the forecast could be completed (Ferry and Brandon, 1991). However, it is necessary to consider the operation, methodology and duration at the same time as they are inter-related. Two factors, mentioned by Ferry and Brandon (1991, p.173) causing this inter-relatedness include;

1. "The need to use labour and plant effectively, so that neither men nor machines stand idle for long periods between tasks, nor are required to be working in two different places at once, nor spend too much time moving from one part of the site to another."

2. "The inescapable sequence of building, so that, for example, the walls and columns cannot be built until the foundations are completed, and the first floor cannot be placed until the ground floor walls and columns have been built."

Two examples of resource-based price models are critical path models and activity bills. The principle behind critical path analysis is that a project is divided into activities of short duration, so that each activity may be scheduled and priced in a logical manner. To provide the financial forecast, the scheduling of a network would include the duration of the activity, the number of workers required, their labour skill classification and the estimated direct costs of labour, plant and materials, on to which a profit can be added (Antill and Woodhead, 1990).

3.4 NON-TRADITIONAL MODELS

In 1984, Brandon (1984) asserted that the use of artificial computer intelligence, and in particular the use of expert systems was likely to have a major impact on the building profession. Brandon (1984) reasoned that, by using 'deductive logic', the 'rule of thumb' approach used by an expert could be incorporated into a computer program which would be able to simulate the knowledge of that expert. Brandon (1984) presented three methods of modelling that he believed could achieve the above statement. They fell into three groups as a result of their flexibility, namely, simulation, regression analysis and expert systems. The writer disagrees with simulation and expert systems as being forecasting models and adopts the view that they are techniques for dealing with uncertainty, rather than actual forecasting models. Two forms of non-traditional forecasting methods will be presented, namely, parametric forecasts and regression analysis. Expert systems are also discussed, not as a forecasting model, but rather as a modelling environment.

3.4.1 REGRESSION ANALYSIS

Regression analysis is a fairly new concept in price forecasting, in that the forecast is expressed as a function of a number of factors or variables that determine its outcome (Barron and Targett, 1985). Regression analysis is a technique that utilises a formula or mathematical model which best describes the relationship of collected data (Ashworth, 1988; Barron and Targett, 1985). This data, which should be calculated with the information of at least 30 projects to make the outcome reliable (Beeston, 1975, 1983; Ferry and Brandon, 1991) is useful as all major factors affecting cost can be included in one formula. The model falls short of being ideal for three reasons (Ferry and Brandon, 1991);

1. The calculated regression represents a model that is true for only that moment in time.
2. Data may be unavailable, in certain periods of building depression, to undertake the analysis unless a regular building program is maintained.
3. Care is often not taken in ensuring that a linear relationship does in fact exist.

According to Makridakis (1978), the principle of regression analysis forecasting is to predict a dependant variable (usually shown on the Y-axis of a graph) by ascertaining how it relates to one or more independent variables (usually indicated on the X-axis of a graph). When a prediction is made on the strength of a single independent variable, simple regression is appropriate, but if additional independent variables are used, then multiple regression analysis is suggested (Makridakis, 1978). The mathematics of simple and multiple regression is not dealt with in this document, as it has been covered adequately in previous publications (Wheelwright and Makridakis, 1985; Makridakis, 1978; Barron and Targett, 1985).

3.4.2 PARAMETRIC FORECASTS

For the purpose of explanation, the method of preparing a parameter forecast will be divided into five stages. The first stage needed to build up a parametric forecast is to identify and select the functional building type to be analysed (eg. schools, hospitals or commercial buildings). Once this has been done, a number of similar cases are chosen for use in the analysis. One of the major shortcomings of this model, is the reliance on the availability of consistent and comparable data to build up the regression equation (Tamarkin, 1971; Krieg, 1979).

The next stage involves the identification of each building chosen in order to develop price forecasting relationships. The projects under scrutiny should be described under a number of characteristics which would form the independent variables, with the dependant variable being the final price of the building.

Stage three involves adjusting the data to take into account factors such as geographic location and annual price variations. This is usually accomplished by means of suitable adjustment indices, which update all data to one location at a specific point in time.

Stage four involves building up forecasting relationships between the independent and dependant variables by means of multivariate analysis. For example, Tregenza (1972) used the relationship between building height and cost, while Tamarkin (1971) used the relationship of cost as a function of area.

Stage five involves evaluating and assessing each condition variable as it relates to the final price of the project by using confidence limits which determine the adequacy of the final equation. According to Tamarkin (1971), the findings obtained in this stage would enable the forecaster to see if his forecast proposals are at the high or low ends of the range. The extremes of the ranges could also be determined. Once the five above mentioned stages have been completed, the final regression equation can be used as a price forecasting model.

3.4.3 EXPERT SYSTEMS

As mentioned in the introduction to non-traditional models, expert systems are seen as an 'modelling environment', rather than as a modelling technique and as such will not be explained here in detail, as a forthcoming chapter has been devoted to this area. The main reason for their inclusion at this stage, is merely to serve as an introduction for the purpose of evaluating the price forecasting models abilities to handle uncertainty, which is dealt with later in this chapter.

Stated very briefly, the expert system environment can be compared to a computer environment which allows rules to be set up which lead to goals or conclusions (Brandon, 1984). These rules according to Brandon (1984), can represent the knowledge that experts 'give' to the computer, with the expert systems program logic being left to deduce the appropriate goal or conclusion.

3.5 UNCERTAINTY IN PRICE MODELS

The eleven modelling methods presented above all have a number of problems and/or disadvantages associated with them which make their existence and validity uncertain. In an attempt to improve this situation, it is necessary to evaluate the potential for uncertainty inducement within the price models, as well as the models' abilities to cope with those uncertainties. The above is presented in two stages. Firstly, a number of criteria for evaluating uncertainty inducement within models will be proposed together with a table which applies these criteria. Secondly, criteria for evaluating the models ability to cope with uncertainty will be presented along with a table applying these criteria.

3.5.1 CRITERIA FOR EVALUATING THE POTENTIAL FOR UNCERTAINTY INDUCEMENT WITHIN MODELS

In this section, nine criteria for evaluating the potential for uncertainty inducement within the modelling environment are presented, together with a brief reason for their inclusion. Although not an exhaustive list, it is felt that the criteria presented are adequate for the purpose of the above evaluation.

a) Amount of information needed by the model

Each of the forecasting models mentioned earlier in this chapter are made up of a number of measurable items. The number of items generally increases as the design progresses towards the tender stage. As the number of measurable items increases, so too does the need for information. Hence, the effectiveness of the model in dealing with any unknown conditions relies on the amount of information available at its time of use.

Availability of information from the architect

e availability of information from the architect increases over the life of the project as more cisions are made by the client and the design team. The more information the quantity rveyor has to prepare his forecast, the less assumptions he will have to make. More formation tends to improve the output accuracy, with detailed data being more valuable an data presented as averages (Georgoff and Murdick, 1986). Hence, a trade off must take ace between the accuracy of the output and the availability of information.

Sources of data

ata are available from many sources. It may take the form of priced bills of quantities, cost ialyses, price lists, price books, indices or specialist quotations. Each source of data has an sociated degree of accuracy and if incorrectly used, may lead to inaccurate forecasts.

) The variability of rates used

ll the price forecasting models rely on a single rate, or combination of rates, in calculating ie total price of the project. As mentioned in Chapter Two, the quantity surveyor is placed in situation where he must predict the rates that the contractor will use in tendering for the roject. The variation in the rates applied to the different models results in a degree of ncertainty, that needs to be allowed for.

) Ability to model the building process

This is an important criteria as the accuracy of a price forecasting method may be high, but if t is unable to model the building process, it may result in an inadequate allowance for any ıncertain variables that may be associated with the building.

) Updating of forecast

It may be necessary to update the data, or the entire forecast from one point in time to ınother. The method of updating the forecast (if applicable to the model) may in itself equire data that is uncertain. Indices are mere predictions and, as such, have no certainty ıssociated with them.

) Capabilities and limitations of models

he eleven models mentioned earlier in this chapter all produce outputs with varying degrees f accuracy according to their individual capacities and capabilities (Ashworth and Skitemore, 982; Morrison, 1984). Each model, because of its inherent capabilities and limitations, has a arying degree of efficiency that needs to be considered when used as the tool to perform the orecast.

) Model consistency

here is no basis for evaluating a model on a single project. The conditions and nature of a articular project may suit a particular model, but when used at the same stage of design on nother project, may produce completely different results. It is therefore necessary to look at he consistency of the models accuracy over a period of time and on a range of projects, to auge its general performance in dealing with any uncertain situations.

) Reliance on forecasters experience

Estimates and forecasts, especially in the early stages of design, are expected to be prepared in very short period of time. An inexperienced quantity surveyor may know exactly how to ompile the forecast, but his inexperience will result in more time being taken in his reparation of the forecast. The experienced quantity surveyor may, over a period of time, ather a number of 'rule of thumb' approaches that enable him to produce the forecast more apidly with a greater degree of confidence and accuracy. The models rely on varying degrees f experience in respect of forecasting in general, as well as experience in the use of the nodel. The amount of experience may therefore prove to be an influencing factor in the accuracy of the forecast.

3.5.2 EVALUATION OF THE POTENTIAL FOR UNCERTAINTY INDUCEMENT WITHIN MODELS

In order to perform this evaluation, it is necessary to consider the extent to which each of the nine criteria listed in the previous section, will have on the overall uncertainty of the final output of the forecast. For example, due to the functional unit method requiring a minimal amount of information, its potential for uncertainty inducement is very high. A complete evaluation of the potential for uncertainty inducement in price models is presented in a summarised format in Table 3.1.

Table 3.1 Potential for uncertainty inducement within forecasting models

	Functional unit	Super	Cubic	Storey enclosure	Approximate quantities	Elemental	Bill of quantities	Resource -based	Parametric	Regression models	Expert systems *
A) Amount of information needed by the model	V high	High	V high	High	Acceptable	Acceptable	Low	V high	High	V high	Low
B) Availability of information from the architect	V high	V high	V high	High	Acceptable	Acceptable	Acceptable	High	High	V high	Acceptable
C) Sources of data	V high	V high	V high	V high	low	low	low	low	High	Acceptable	V low
D) Variability of rates used	V high	High	V high	V high	Acceptable	Acceptable	Acceptable	Low	--	High	Low
E) Ability to model the building process	V high	High	V high	High	Acceptable	Acceptable	Low	V low	V high	High	V low
F) Updating of the forecast	V high	V high	V high	V high	High	Acceptable	Low	V high	V high	High	Low
G) Capabilities and limitations of model	V high	High	V high	V high	Acceptable	Acceptable	Low	V low	High	High	Low
H) Model consistency	V high	High	V high	V high	Low	Low	Low	Acceptable	High	Acceptable	V low
I) Reliance on forecasters experience	V high	V high	V high	V high	V high	Acceptable	Low	V high	Low	Low	V low

* Expert systems are not viewed as a forecasting model, but rather as a modelling environment

From Table 3.1, it is apparent that the functional unit, superficial area, cubic, storey enclosure, resource-based and parametric methods of price modelling have an unacceptably high overall potential for uncertainty inducement. It is found that the approximate quantities, elemental, bill of quantities and expert system methods have an acceptable level of uncertainty inducement.

Of the eleven price forecasting methods presented, it can be said that expert systems have the lowest potential for uncertainty inducement.

3.5.3 CRITERIA FOR EVALUATING THE MODELS ABILITY TO COPE WITH UNCERTAINTY

In this section, six criteria for evaluating the forecasting models' ability to cope with different types of uncertainty will be presented. The ability to handle uncertainty is seen as distinct from the models potential for inducing uncertainty. Although not an exhaustive list, it is felt that the criteria presented are adequate for the purpose of the above evaluation.

a) General form of model

The form of each model is useful to the evaluation as it gives an indication of the variables that contain the uncertainty. The price of all the models mentioned in the chapter are expressed in one or other function of quantity and rate. Therefore any single, or combination of the variables of price, quantity and rate determine the extent to which uncertainty has, or has not been allowed for in the forecast.

b) Adaptability and flexibility of model

In order for a model to take variable factors such as uncertain soil conditions, or the prices of imported materials into account, and provide for ease of forecast updating, it is necessary that the model be flexible in its application. Linked to the adaptability, is the extent to which the model could provide the user with any meaningful output in respect of cost implications of design alternatives.

c) Number of items

As mentioned under (a) above, the end price of the forecast is determined by the multiplication of a single quantity by a single rate, or the summation of several single quantities by single rates. It follows that the inclusion of more items into the models form will result in a high probability for the inclusion of uncertain variables. The situation is made worse by the addition of several items, that in themselves are uncertain, thereby compounding the problem of the total uncertainty of the forecast.

d) Availability of information

The availability of information has a direct effect on the item rates and quantities that need to be measured and priced. If the information is not known with certainty, or unavailable when needed, the determination of the quantities or price cannot be known with certainty.

e) Derivation of the measured quantities

The stage at which the measurable quantity is determined has a great influence on the outcome of the forecast because of its multiplication by a monetary rate. Because of the lack of precise knowledge and information at an early stage in the design process, it is difficult for the quantity surveyor to be certain of the exact quantities that need to be used.

f) Variability of rates

Traditional models tend to use a single figure rate in the production of a forecast, thereby assuming certainty of that rate. This is not truly possible, nor probable, since the quantity surveyor has little idea of the rates that the contractor will use in producing his tender price. As indicated in Chapter Two, the variability of unit rates can differ considerably and at best, the quantity surveyor can only produce a range of possible rates along with a measure of the probability of each rates outcome.

3.5.4 EVALUATION OF THE MODELS ABILITY TO COPE WITH UNCERTAINTY

In order to perform this evaluation, it is necessary to consider the extent to which the forecasting model makes allowance for each of the criteria listed above. For the purpose of evaluating certain of the criteria it is necessary to consider two factors. Firstly, the objective response to the criteria, and then an assessment of whether that response is able to cope with uncertainty. Table 3.2 summarises the traditional models' ability to cope with different forms of uncertainty.

It can be seen from Table 3.2 that the functional unit, superficial area, cubic, storey enclosure, parametric and regression price models are unable to cope with the types of uncertainty presented above. From Table 3.2, it can be concluded that the expert system environment is best suited to deal with the uncertainty associated with price forecasting.

Table 3.2 Forecasting models under conditions of uncertainty

GENERAL INFORMATION

	Functional unit	Super	Cubic	Storey enclosure	Approximate quantities	Elemental	Bill of quantities	Resource -based	Parametric	Regression models	Expert systems *
Model format	$P = q.r$	$P = q.r$	$P = q.r$	$P = q.r$	$P = \Sigma q_i.r_i$	$P = \Sigma q_i.r_i$	$P = \Sigma q_i.r_i$	$P = \Sigma q_i.r_i$	$P = f_r . (q_1 q_2 q_3 ..)$	$P = a+\Sigma q_i b_i+e$ $e = N(0,\sigma^2)$	--
Deterministic/ Probabilistic	Det	Det	Det	Det	Det/Prob	Det	Det/Prob	Det	Det	Det/Prob	Det/Prob
number of items	Single	Single	Single	Single	Medium/few	Medium	V many	V many	Few	Few	V many

ABILITY OF MODEL TO COPE WITH UNCERTAINTY

	Functional unit	Super	Cubic	Storey enclosure	Approximate quantities	Elemental	Bill of quantities	Resource -based	Parametric	Regression models	Expert systems *
General format of model	V bad	V bad	V bad	V bad	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	--
Adaptability and flexibility of models	V bad	Bad	V bad	V bad	Acceptable	Acceptable	Good	Acceptable	Bad	Bad	Very good
Number of items	V bad	V bad	Bad	V bad	Bad	Acceptable	Acceptable	Good	Acceptable	Acceptable	V good
Availability of information	V bad	V bad	Bad	Bad	Acceptable	Acceptable	Good	Acceptable	Bad	Bad	V good
Variability of rates	Bad	Bad	Bad	Bad	Acceptable	Acceptable	Acceptable	Good	Bad	Bad	Good
Derivation of measured quantities	V bad	V bad	Bad	V bad	Acceptable	Acceptable	Acceptable	Good	Acceptable	Acceptable	Good

* Expert systems are not viewed as a forecasting model, but rather as a modelling environment

3.6 CLASSIFICATION OF MODELS WITH REFERENCE TO UNCERTAINTY

Having presented the price models' abilities to handle uncertainty, it is possible to offer a classification of the forecasting methods with reference to uncertainty. As it is intended to re-evaluate the price model classification at a later stage, a linear deterministic/probabilistic classification has been adopted (Raftery, 1984a, 1987; Bowen and Edwards, 1985; Bowen *et al.*, 1987; Newton, 1991a; Skitmore and Patchell, 1990).

The purpose of this classification is to distinguish between those price models that do have a formal measure of uncertainty (Newton, 1991a), and those that acknowledge the uncertainty of future events (Bowen and Edwards, 1985). This classification has been included in Table 3.2.

It has been stated that the potential for uncertainty inducement within the price models is high. It was also stated that the majority of the price models presented were unable to cope with the uncertainty associated with the price forecasting process. In the following chapter, several techniques that are able to 'measure' uncertainty are presented.

CHAPTER 4

EVALUATION OF TECHNIQUES FOR DEALING WITH UNCERTAINTY

4.1 INTRODUCTION

In Chapter Three several models used to forecast the price of a project were presented together with an evaluation of their ability to deal with the uncertainties present in the building industry. In order to achieve a successful forecast of price, it is sometimes necessary to make decisions based on information that is of an uncertain nature. According to Paterson (1987), this uncertainty can be approached in a systematical manner in order to make the best use of all the information at hand, no matter how uncertain it may be. One of the ways to overcome this problem in decision making is to use techniques that measure the uncertainty of events, and use their 'cumulative' total as a basis to weigh the validity of the final forecast.

The purpose of this chapter is to review some of the statistical techniques that are able to 'deal' with uncertainty in general, discuss their ability to deal with the uncertainty in the design process, and finally, to look at the techniques' suitability for implementation in the price forecasting model.

4.2 TECHNIQUES TO HANDLE UNCERTAINTY

Uncertainty can occur in an infinite number of forms (Fox, 1986), but to date, no techniques exist that are able to totally handle all forms of uncertainty (Mamdani *et al*, 1985; Marshall, 1988). It is therefore necessary to evaluate and draw characteristics from some of the methods used to deal with uncertainty so that the best possible solution can be found to handle the different circumstances that present themselves to us (Scott *et al.*, 1988). Of the many available techniques that attempt to deal with uncertainty, seven have been chosen for the purpose of this study. They are Probability theory, Bayesian theory, Certainty factors, Fuzzy logic, Possibility theory, Decision tree analysis and Simulation. These seven techniques have been chosen on the basis of their popularity within literature publications dealing with the subject of uncertainty.

At this point, it should be noted that the techniques mentioned in this chapter do not (and cannot) transform a problem into something which is completely quantifiable, but they do provide an aid to handling the problem of uncertainty more systematically (Cohen, 1985; Toakley, 1989 and Marshall, 1988).

4.2.1 PROBABILITY THEORY

Probability theory is arguably the most important technique for dealing with uncertainty, as many of the other approaches that try to handle uncertainty are based on this theory. The major difference being that the latter methods try to correct the areas where uncertainty is unable to be handled by probability theory.

Finding a definition for probability is difficult, as statistics is not the precise subject it is believed to be (Barrow, 1988). There are many differing schools of thought with the most popular being that of the ‘frequentists or objectivists’. This school asserts that the probability of a hypothesis is taken by looking at the proportion of the occurrence as the number of iterations tends towards infinity (Carnap, 1950). Problems arise with objective probability theory, as it is impossible to perform an infinite number of iterations. Furthermore, the same test would have to be performed again with any new data. The approach also fails as it is unable to measure a number of probabilities. For example, it would not be able to give the probability of a company going insolvent unless the life of the company could be played back an infinite number of times to record its results each time.

Another method of looking at probability is through the subjective approach established in the twentieth century by Ramsey, de Fietti, and Savage (Shafer, 1987). This school disregard the ‘frequentists’ and believe that probability is the ‘degree of belief’ held by the individual, of that particular event occurring. The probabilities of the outcomes are mutually exclusive and lie between;

$0 \leq P(A) \leq 1$ where
$P(A) = 1$ signifies that A is certain to occur
$P(A) = 0$ signifies that A is certain not to occur

A problem arises with this approach with regards to the origin of prior beliefs, and the inability of the method to handle the updating of beliefs. The subjectivists assert that prior belief can be acquired by asking the opinion of an expert, as long as the decision criteria remain small (Shortliffe and Buchanan, 1984). Tversky and Kahneman (1974) believe that researchers place too much faith in small samples and then overestimate the reliability of the results. Lindley (1987) promotes the probability approach as being the ‘best’ method presently available to handle uncertainty.

4.2.2 BAYESIAN THEORY

The major difference between the Bayesian and Frequentist approach is that the former can handle the updating of belief while the latter can not. This theory allows all the available knowledge of a problem to be bought into account by assigning probabilities to all chance events (Toakley, 1989). Bayesian theory was introduced by the Reverend Thomas Bayes who suggested that for every event there be a prior probability of it happening, even if that probability is so small that it equals zero (Scott *et al.*, 1988). In this context, uncertainty is viewed as a probability, numerically represented between the values of 0 and 1 (Henkind and Harrison, 1988: Pang *et al.*, 1987).

Henkind and Harrison (1988) provide two advantages for the use of the Bayesian approach. Firstly, the computational methods based on the Bayes' rule have an axiomatic foundation and well-understood mathematical properties and secondly, the computation time is relatively short.

One of the most important shortcoming, according to Shafer (1987), Henkind and Harrison (1988) and Pang *et al.* (1987), is the methods inability to explain how the quality of a probability analysis depends on the availability and quality of relevant evidence. This means that if a piece of evidence is only partially in favour of a hypothesis, it would also have to be partially supporting the negation of that hypothesis so as to satisfy the requirements of Bayes theory.

According to Adams (1984) and Henkind and Harrison (1988), the suitability of the technique is questionable, as the lack of adequate data to accurately estimate the *a priori* and conditional probabilities in the theorem, is limited.

4.2.3 CERTAINTY FACTORS

This approach was introduced by Shortliffe and Buchanan in the 1970's during the inception stages of the development of the expert system "MYCIN" (Buchanan and Shortliffe, 1984). Certainty factors can be described as the difference between the measure of belief and disbelief in a given hypothesis (Pang *et al*, 1987; Scott *et al.*, 1988; Henkind and Harrison, 1988. According to Shortliffe and Buchanan (1984), certainty factors provide a useful way to think about confirmation and the quantification of degrees of belief, and can be represented algebraically by;

$$CF = MB - MD$$

Where MB = measure of belief
and MD = measure of disbelief

Represented numerically (Scott *et al.*, 1988), the certainty factors fall in the range;

-1 ≤ CF ≤ +1 , where
+1 represents complete belief
-1 represents complete disbelief
0 represents ignorance

Although many authors have used certainty factors that lie between the ranges of -1 and +1, others have avoided the use of negative numbers. The Dempster-Schafer theory of evidence (Gordon and Shortliffe, 1984) uses a number in the range [0 - 1] to indicate belief in a hypothesis, given a piece of evidence. The certainty factor represents the degree to which the user believes that the stated evidence supports the given hypothesis (Scott *et al.*, 1988).

One of the problems relating to certainty factors and mentioned by Henkind and Harrison (1988), is the computational expense of storing separate measures of belief and disbelief. A more serious problem is that one piece of disconfirming evidence can overwhelm many pieces of confirming evidence, and *vice versa* (Henkind and Harrison, 1988).

4.2.4 FUZZY LOGIC

Fuzzy set theory, first proposed by Zadeh in 1965 as a mathematical theory of vagueness (Zadeh, 1965), is a set of elements in which there is no crisp boundary between those elements that belong to the set, and those that do not (Bellman and Zadeh, 1970; Henkind and Harrison, 1988; Toakley, 1989). Typical examples are;

A = { x: x is a low level of certainty}
B = { y: y is much larger than 10}

Although no precise membership is given, the fuzzy statements do convey meaningful information (Toakley, 1989).

According to Mamdani and Efstathiou (1985), fuzzy logic regards uncertainty as fairly homogeneous, classifying it into probabilistic, non-probabilistic and possibilistic classes. Although the subject of fuzzy sets has been widely publicised, Kicket (1978) states that most of the research work conducted in the field of fuzzy sets is of a theoretical rather than a practical nature. In response to the views of Kicket (1978) and others, Zadeh (1980), although admitting to the controversy surrounding the theory, maintains that fuzzy sets are;

> "aimed at the development of a body of concepts and techniques for dealing with sources of uncertainty or imprecision which are non-statistical in nature" (Zadeh, 1980, p.421).

The basic notion of fuzzy sets is best summarized by Toakley (1989) in the form of an example.

If we take the example

B = { y: y is much larger than 10}
and **C** is a subset **B**

then the fuzzy subset **C** can be subjectively defined as the collection of ordered pairs (Toakley, 1989)

C = { (12, 0.8), (20, 0.6), (15, 0.6) }

with each ordered pair having two objects, the first (12) representing an element from the set **B**, and the second (0.8), representing a degree of membership that 12 has in the set. The degree of membership always takes a value between 0 and 1, with 1 denoting the object to be a member (or truth) of the set, 0 denoting non-membership (or falsity) and any intermediate values denoting partial membership to the set (Henkind and Harrison, 1988; Scott *et al.*, 1988; Toakley, 1989).

Fuzzy logic is useful when data is characterised by linguistic variables (Lesmo *et al.*, 1985; Toakley, 1989) such as low certainty or high certainty, as it allows for easy and natural specifications for imprecise concepts (Bonisonne and Tong, 1985; Henkind and Harrison, 1988; Toakley, 1989).

One of the advantages of Fuzzy set theory, according to Henkind and Harrison (1988), is its low information and time complexities. Although flexible in nature due to a number of ways in which the problem can be formulated, this flexibility can also lead to problems since little guidance as to which methods to use to solve a given problem is given (Henkind and Harrison, 1988).

4.2.5 POSSIBILITY THEORY

Zadeh (1978), as an extension of his theory of fuzzy sets, devised possibility theory in an attempt to overcome the difficulties in representing inexact or vague information by using probabilistic theory (Ng and Abramson, 1990). It was Zadeh's intention to express these vague terms with precision and accuracy (Ng and Abramson, 1990). As an extension of the possibility theory proposed by Zadeh, Dubois and Prade (1984), proposed an approach that is capable of dealing with uncertainty.

In answering certain problems, human experts use terms such as 'maybe', 'likely' and 'probably' to logically explain their solutions. Looking at these concepts in a probabilistic environment, the event either occurs or it does not, with the result that a specific point value is assigned to the 'fuzzy' piece of evidence. The intention of possibility theory is to make an allowance for the grey areas surrounding the 'fuzzy' pieces of evidence (Ng and Abramson, 1990).

Stated briefly, possibility theory uses two numbers in the range [0 1], $\pi(p)$ and $\pi(\sim p)$, such that the possibility that p is true and the possibility that p is false, equal 1 (Pang *et al.*, 1987). It should be noted that the numbers assigned to possibility theory differ from those of probability theory, fuzzy set theory and certainty factors in two ways (Ng and Abramson, 1990). Firstly, no restrictions exist on the sum of the possibility outcomes, whereas the sum of the prior mentioned theories, must equal 1. Secondly, the values assigned in possibility theory have no direct relationship between those used by the three afore mentioned theories. These two differences can be shown by means of the example given by Zadeh (1978), cited by (Ng and Abramson, 1990, p.38); "If John can eat 1 to 3 eggs for breakfast, the possibility that John can eat 1, 2, 3 eggs may be set as 0.9, 1.0, 1.0, respectively. However, the probability that John will eat 1,2 or 3 eggs on an arbitary morning may be 0.1, 0.7, and 0.2."

4.2.6 DECISION TREE ANALYSIS

Decision tables are methods of organizing and documenting logic in a manner that allows easy inspection and analysis (Montalbano, 1974; Metzner and Barnes, 1977), as well as facilitating the testing of a set of rules for conditions of ambiguity, redundancy, and completeness (Cragun and Steudel, 1987). Although decision criteria were originally devised to make decisions without incorporating uncertainty and risk, decision trees can be extended to handle these characteristics (Byrne and Cadman, 1984; Marshall, 1988). In general, decision tree analysis allows large or complex decision problems to be broken down into smaller sub-problems which can be solved separately, and then re-combined (Shore, 1978).

According to Spetzler and Staël von Holstein (1975), decision analysis usually involves three phases, namely, the deterministic, probabilistic and informational phases. The deterministic phase involves defining the variables and characterising their relationship in formal models, after which values of possible outcomes can be assigned. In the probabilistic phase, uncertainty is incorporated by assigning probability ranges to the relevant variables. In the informational phase, the economic value of information is determined by calculating the worth of reducing uncertainty about each of the important variables in the problem (Spetzler and Staël von Holstein, 1975).

A decision tree starts at a single point where the decision process commences. From this point, all possible actions are indicated by means of branches which end with outcome nodes. For each given action, there are several possible outcomes which are also represented by branches ending with action nodes. This action-outcome sequence moves from left to right like a branching 'tree', representing the complete array of all possible actions and outcomes (Shore, 1978).

Numerical values are then assigned to the appropriate points, with probabilities given to any uncertain outcomes. A scale from 0 (certain not to occur) to 1 (certain to occur) is normally used as a measure of the event occurring (Birnie and Yates, 1991). Once this has been completed, the process is reversed, and the decision maker moves backwards from right to left. As each decision node is reached, the action having the greatest profit or smallest loss is chosen, and rolled back to the next decision point (Shore, 1978).

Toakley (1989), gives three advantages of decision tree analysis. These are;

1. The construction of the tree may stimulate new ideas as to how the project can be handled.
2. It forces the decision maker to assess the probability of an outcome occurring, and
3. It provides a means of organising ideas into a sensible and structured framework.

4.2.7 SIMULATION

According to Bowen (1984) and Bennet and Ferry (1987), probabilistic simulation models (for example Monte Carlo simulation) permits uncertainty to be treated explicitly as the variable input factors to the model are modelled as probability distributions.

Simulation is a means of creating a typical life-history of the system and activities under given conditions (Ferry and Brandon, 1991; Toakley, 1989). According to Bennet and Ormerod (1984), the purpose of simulation is to imitate the conditions of a system so as to mimic the important elements of the system under study. This is accomplished by producing a predicted likely range, feasible under the conditions and constraints of the project. With the use of computers to perform the numerous iterations, a likely distribution range of values giving possible future cost solutions can be obtained.

Simulation can handle incomplete information (Bowen, 1984), assuming that subjective probabilities can be assigned to (uncertain) outcomes of alternatives, thereby forming a probability distribution. This probability distribution is a set of all possible outcomes of a given strategy with their respective probabilities (Koutsoyannis, 1982). The resultant possible outcomes can then be measured by the weighted average distance of the (uncertain) outcomes from the mean value (*ie.* by working out the standard deviation) of the given condition (Bowen, 1984).

Due to the number of iteration and calculations needed to produce a feasible solution, the use of a computer is essential to speed up the calculation time (Marshall, 1988).

4.3 THE SUITABILITY OF UNCERTAINTY TECHNIQUES TO HANDLE FORECASTING UNCERTAINTIES

In order to draw a conclusion as to whether the techniques discussed above can deal with the types of uncertainty present in the price forecasting process, two factors need consideration. Firstly, the ability of the uncertainty technique to model the types of uncertainty present in the period of price forecasting and, secondly, the suitability of the uncertainty technique to be incorporated in the forecast model. Each of these factors will be dealt with by, firstly, listing suitable evaluation criteria and, secondly, by evaluating the criteria against the technique and forecasting model respectively.

4.3.1 CRITERIA FOR EVALUATING TECHNIQUES ABILITY TO HANDLE UNCERTAINTY

In this section, seven criteria for evaluating the uncertainty techniques mentioned earlier in this chapter will be presented, together with a brief reason for their inclusion. Although not an exhaustive list, it is felt that the criteria presented are adequate for the purpose of the above evaluation.

a) Suitability of technique for the building process

The seven techniques presented above are all able to deal with some form of uncertainty and, as such, have strengths and weaknesses that lie in different areas. It is therefore appropriate and necessary to evaluate the overall strengths and weaknesses of each technique, in respect of its applicability and suitability to the building process in general.

b) Amount of subjectivity needed in the use of the technique

In order to treat uncertainty, it is necessary to know with what objectivity or subjectivity the technique was applied. It would be useful to know this degree of subjectivity in order to apply possible limits or measures of belief to the resultant outputs. For example, in probability theory, if the probability assigned to an event occurring was said to be, say 50%, but was applied subjectively, an allowance for the uncertainty has been made, but the output has in itself, an element of uncertainty attached to it. It is this subjectivity in the use of the technique that needs to be known.

c) Does technique produce a meaningful result

One of the problems associated with traditional models, according to Ferry and Brandon (1991) and Amkreutz (1976), is the 'black box' effect they have on the output of the forecast model, *ie.* they are unable to explain or show the user how their results were obtained. It is, therefore, appropriate to consider how meaningful the results obtained from the techniques use are to all parties involved.

d) Variability of data

One of the problems highlighted in Chapter Two, was the variability associated with the data used by the quantity surveyor in compiling the price forecast. It was shown that this variability could lead to uncertainty, and would therefore need to be minimised if a truly accurate and meaningful forecast was to be produced. It is therefore appropriate to consider whether the uncertainty technique can take this variability of data into account when applied to a problem situation.

e) Ease of implementation

Each of the uncertainty techniques has a different form which may, or may not, be suitable for incorporation into the form of the forecasting model. The technique may be 'perfect' for handling a type of uncertainty present in the building process, but if its implementation into one of the forecasting models is difficult, or impossible, it is unsuitable for use in that model.

f) Time needed for calculation

The time needed in performing the uncertainty calculation or adjustment is a major consideration that must be taken into account, as it is sometimes necessary to provide the client or architect with a cost forecast within a very short period of time. If the time needed in performing the calculation was very lengthy, it would, for example, be inappropriate to use it at the inception stage of design, were the client or architect needed a forecast within a few minutes.

g) Number of iterations needed

Some of the techniques need to perform several iterations every time they are applied to a problem in order to achieve their maximum effectiveness. The amount of iterations needed, in order to achieve this effectiveness, may take a long time to perform, thereby rendering it unsuitable for the same reason as discussed under (f) above.

Some of the techniques, due to their mathematical computations, may require the use of a computer to perform mathematical calculations. Some of the factors that would need to be considered if the technique was to require a computer would be the cost of the computer (if office did not have one initially), the maintenance thereof, the initial installation of technique into the forecasting model and the need for trained personnel to use the 'package'. These factors may render the technique non-feasible, in which case, its use may be meaningless for the needs of certain individuals.

4.3.2 EVALUATION OF TECHNIQUES TO MANAGE THE UNCERTAINTY IN FORECASTS

In order to perform this evaluation, it is necessary to consider the extent to which the uncertainty technique is able to cope with the uncertainties associated with the pricing process. Table 4.1 summarises the techniques abilities to cope with different forms of uncertainty, mentioned in the above section.

The above mentioned evaluation is presented for the purpose of indicating the suitability of each technique to the uncertainties associated with the price forecasting process in general. It is not intended to deal with the uncertainties associated with each individual price model, as this evaluation is dealt with in the following section.

From the results of the evaluation, it can be concluded that all seven techniques are suitable to handle the uncertainty associated price forecasting.

Table 4.1 Suitability of technique to handle uncertainty

	Probability theory	Bayesian theory	Certainty factors	Fuzzy logic	Possibility theory	Decision tables	Simulation
Suitability of technique to model the building process	V good	Acceptable	Acceptable	Good	Acceptable	V good	V good
Amount of subjectivity needed in the use of the technique	V high	V high	High	Acceptable	High	Acceptable	Good
Does technique produce a meaningful result	V good	V good	V good	Good	Good	V good	V good
Variability of data	Good	Good	Good	Acceptable	Bad	V good	V good
Ease of implementation	Good	Acceptable	Bad	Bad	Bad	Good	Good
Time needed for calculation	Good	Acceptable	Acceptable	Bad	Bad	Bad	Bad
Number of uses of technique to achieve maximum effectiveness	Single	Single	Single	Single	Single	Many	V many

4.4 THE SUITABILITY OF TECHNIQUES TO FORECASTING MODELS

Having evaluated the techniques' abilities to cope with the uncertainty in the price forecasting process, it is now possible to consider the extent to which the techniques may be implemented in the individual price forecasting models.

4.4.1 CRITERIA FOR EVALUATING THE TECHNIQUE/MODEL INTERFACE

In this section, the uncertainty technique is evaluated against the forecasting models with the aid of four criteria. Hence, the suitability of the uncertainty technique to the price forecasting model can be ascertained. As in previous sections, the criteria are presented together with a brief reason for their inclusion. Although not an exhaustive list, it is felt that the criteria presented are adequate for the purpose of the above evaluation.

a) Ability an suitability to cope with uncertainties within model

The intention of this criteria is to evaluate the techniques ability to deal with the uncertainty factors present in each of the forecasting model as a whole.

b) Consistency of output accuracy

In considering the consistency of implementation, the average expected final accuracy level of the technique, as well as the meaningfulness of the output to the end users, would serve as a useful guide in gauging the final acceptance of the technique into the model by the practitioner.

c) Ease of implementation

The ease of which the uncertainty technique could be incorporated into the forecasting model would be determined by factors such as personnel availability, the time available to produce the forecast, and the familiarity of the user with workings of the uncertainty technique. Also associated with the ease of technique implementation, is the suitability of the uncertainty techniques format, to that of the price models.

d) Cost

The possible need for a computer, trained personnel, or lengthy calculation time may render the techniques application to 'costly' in terms of the practitioners resource availability.

4.4.2 ABILITY OF PRICE MODEL TO INCORPORATE THE UNCERTAINTY TECHNIQUE

The extent to which the uncertainties techniques are able to be incorporated by the forecasting model, is summarised in Table 4.2. Based on the criteria presented above, it can be concluded that the seven techniques used to treat uncertainty are suitable for implementation into the majority of price models.

	Functional unit	Super	Cubic	Storey enclosure	Approximate quantities	Elemental	Bill of quantities	Resource -based	Parametric	Regression models	Expert systems*
1. PROBABILITY THEORY											
a) Ability & suitability to cope with uncertainty in model	V good	Good	Good	Acceptable	V good	V good	V good	Good	V good	Good	Good
b) Consistency of output accuracy	Acceptable	Good	Good	Good	Acceptable	Acceptable	Acceptable	V good	Good	Acceptable	Good
c) Ease of implementation	V good	Acceptable	Good	Acceptable	V good	V good	V good	V good	Acceptable	Acceptable	V good
d) Cost	V good	Acceptable	Acceptable	Good	V good	V good	V good	V good	Acceptable	Acceptable	V good
2. BAYESIAN THEORY											
a) Ability & suitability to cope with uncertainty in model	Good	Acceptable	Acceptable	Good	V good	V good	V good	Good	Good	Good	Good
b) Consistency of output accuracy	Good	Good	Good	Acceptable	Acceptable	Acceptable	Acceptable	V good	Good	Acceptable	Good
c) Ease of implementation	Acceptable	Acceptable	Acceptable	Good	V good	V good	V good	V good	Acceptable	Acceptable	V good
d) Cost	Good	Acceptable	Acceptable	Good	V good	V good	V good	V good	Acceptable	Acceptable	V good
3. CERTAINTY FACTORS											
a) Ability & suitability to cope with uncertainty in model	Acceptable	Good	Good	Acceptable	Good	Good	V good	V good	Acceptable	Good	V good
b) Consistency of output accuracy	Good	Good	Good	Acceptable	Good	Good	Acceptable	Good	Acceptable	Good	Good
c) Ease of implementation	Bad	Acceptable	Good	Good	Good	Good	Good	Good	Bad	Bad	V good
d) Cost	Bad	Acceptable	Acceptable	Good	V good	V good	V good	V good	Bad	V bad	V good
4. FUZZY LOGIC											
a) Ability & suitability to cope with uncertainty in model	V good	V good	V good	Good	V good	V good	Good	Acceptable	V good	Good	V good
b) Consistency of output accuracy	Good	Good	Good	Good	V good	V good	Good	V good	V good	Acceptable	Good
c) Ease of implementation	V bad	V bad	Bad	Acceptable	Good	Good	Good	Acceptable	Bad	V bad	V good
d) Cost	V bad	Bad	Acceptable	Acceptable	Acceptable	Acceptable	Good	Good	V bad	V bad	Good
5. DECISION TREES											
a) Ability & suitability to cope with uncertainty in model	V good	V good	Good	Good	V good	V good	Good	V good	Good	Acceptable	V good
b) Consistency of output accuracy	V good	Good	Good	Good	V good	V good	V good	V good	V good	Acceptable	V good
c) Ease of implementation	V bad	Bad	Acceptable	Good	Good	Good	V good	V good	V bad	V bad	V good
d) Cost	V bad	Bad	Bad	Acceptable	Good	Good	Acceptable	V good	V bad	V bad	V good
6. POSSIBILITY THEORY											
a) Ability & suitability to cope with uncertainty in model	Good	Acceptable	Acceptable	Good	Good	Good	Acceptable	Acceptable	Acceptable	Good	Good
b) Consistency of output accuracy	Acceptable	Acceptable	Good	Acceptable	Acceptable	Acceptable	Acceptable	Good	Acceptable	Good	Good
c) Ease of implementation	Bad	Acceptable	Bad	Good	Good	Good	V good	V good	Bad	Bad	Good
d) Cost	Bad	Bad	Acceptable	Acceptable	Good	Good	V good	V good	Bad	V bad	Good
7. SIMULATION											
a) Ability & suitability to cope with uncertainty in model	Bad	V good	Acceptable	Good	Good	V good	V good	V good	V good	Acceptable	V good
b) Consistency of output accuracy	Good	V good	Good	V good	V good	V good	V good	V good	V good	Good	V good
c) Ease of implementation	Bad	Acceptable	Acceptable	Good	Acceptable	Good	V good	V good	V bad	Bad	V good
d) Cost	Bad	Bad	Bad	Acceptable	Good	Good	V good	V good	V bad	V bad	V good

* Expert systems are not viewed as a forecasting model, but rather as a modelling environment

Conclusion

Until fairly recently, the provision of uncertainty within cost modelling has usually been described by practitioners in phrases such as ‘the preliminary nature of the budget’ or ‘indicative appraisal only’ or ‘contingency allowance’ (Hawkins and Soloman, 1989).

The results obtained from this chapter have indicated that techniques of treating the uncertainty associated with price forecasting, do exist. It has also been concluded that these techniques are suitable for incorporation into the price forecasting models used by practitioners.

With the aid of probabilistic measures, the amount of uncertainty and incomplete data within price models can be handled with fair assurance, enabling the quantity surveyor to produce a more certain forecast of the intended project for the client and architect.

The following chapter presents the findings of a questionnaire survey on the nature and treatment of uncertainty in the quantity surveying practice.

CHAPTER 5

METHODS USED BY PRACTITIONERS TO HANDLE UNCERTAINTY

5.1 INTRODUCTION

As mentioned in Chapter One, a questionnaire survey was conducted to determine the extent to which practitioners deal with the various forms of uncertainty in performing their building price forecasts. This survey, which served as the major source of primary information for this report, was in the form of three different questionnaires sent to quantity surveying, client and architectural offices, respectively, on a nation-wide basis.

The purpose of the survey was to gather research information from practitioners for use in a doctoral thesis and four undergraduate theses. Although the subject matter in the five research projects is closely related, for the purpose of this report only the sections which have relevance to the uncertainty within price-forecasting will be presented and analysed. However, before any analysis is made, it is necessary to give a short overview of the procedure followed in obtaining these results.

The objective of this chapter is to establish the methods of price modelling used in practice, as well as any techniques that practitioners may use to deal with the uncertainty associated with price forecasting. It will also be argued that the price forecasts made by practitioners could be improved if certain allowances were to be taken into account at the time the forecast is prepared.

5.1.1 QUESTIONNAIRE DESIGN

Once the decision to compile a survey had been made, each researcher prepared a summary of information that he/she would need for their respective reports. Appropriate questions were then devised. Certain of the questions contained in the questionnaire surveys conducted by Grieg (1981), Morrison (1983) and Billet (1990) have been included in this questionnaire, as they were felt to be pertinent to the survey. It was decided to offer a scale of alternative answers to most of the questions (Oppenheim, 1966), as they do not have a 'correct' or 'incorrect' answer. These 'scales' are in the form 'always, frequently, occasionally, seldom and never', 'very good, good, acceptable, poor, very poor' or 'very high, high, acceptable, little and none'.

5.1.2 SURVEY SAMPLE AND DISTRIBUTION

In order to get the best possible reaction and meaningful response, it was necessary to send a questionnaire to all quantity surveying, architectural and client offices in South Africa. The names and addresses of the persons involved in the survey sample were obtained from the mailing lists of quantity surveying practises, architectural offices and client bodies, supplied by the Association of South African Quantity surveyors, the Institute of South African Architects, and the South African Property Owner's Association, respectively. A list of public sector quantity surveying, architectural and client offices was added to the initial sample, as the mailing lists provided by the above bodies did not incorporate this information.

The questionnaires were mailed to the relevant people together with two covering letters, a list of definitions, and a freepost envelope. The main covering letter, written by Professor Bowen of the University of Cape Town, explained the purpose and nature of the questionnaire, as well as giving relevant information about the return dates and estimated questionnaire completion time. The second covering letter, prepared by Professor Le Roux of the University of Port Elizabeth, was included in an attempt to gain a greater sample response. The list of definitions was included for the purpose of clarifying any terms that the respondents may have found misleading.

It was decided to extend the initial time given for the questionnaire returns, as the first response to the questionnaire totalled 9%. According to Doctor Dunne, a mathematical statistician, the normal expected first response to a survey of this kind, is about 10%. A telephonic follow up was then conducted to all offices who had not sent in a return. The response results are summarised in Table 5.1, Table 5.2 and Table 5.3.

Table 5.1 Results of quantity surveyors survey questionnaire

			PROVINCE												SECTOR			
TOTAL NUMBER OF QUESTIONNAIRES	549		W. Cape		E. Cape		S. Tvl		N. Tvl		Natal		O.F.S		Private		Public	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
TOTAL LEGITIMATE SAMPLE	496	100	72	14	64	13	94	20	142	28	80	16	44	9	457	92	39	8
TOTAL RESPONSES	99	20	22	22	6	6	20	20	13	13	27	26	12	12	95	96	4	4

Table 5.2 Results of architect survey questionnaire

			PROVINCE												SECTOR			
TOTAL NUMBER OF QUESTIONNAIRES	1289		W. Cape		E. Cape		S. Tvl		N. Tvl		Natal		O.F.S		Private		Public	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
TOTAL LEGITIMATE SAMPLE	1115	100	188	17	83	7	361	33	246	22	188	17	49	4	1080	97	35	3
TOTAL RESPONSES	99	9	20	21	14	14	14	14	21	21	21	21	9	9	98	99	1	1

Table 5.3 Results of client survey questionnaire

			PROVINCE												SECTOR			
TOTAL NUMBER OF QUESTIONNAIRES	750		W. Cape		E. Cape		S. Tvl		N. Tvl		Natal		O.F.S		Private		Public	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
TOTAL LEGITIMATE SAMPLE	399	100	71	18	19	5	180	45	62	16	49	12	18	4	358	90	41	10
TOTAL RESPONSES	124	31	31	25	7	6	53	43	15	12	12	9	6	5	114	92	10	8

As a result of the telephonic survey, it was found that the sample size could be reduced for a number of reasons. These reasons are presented in a summarised form in Table 5.4.

Table 5.4 Breakdown of total survey sample

	CLIENTS	ARCHITECTS	QUANTITY SURVEYORS	TOTAL
Total sent	750	1289	549	2588
LESS :				
Not applicable	294	28	24	346
Did not receive	21	90	25	136
Returned to sender	7	7	2	16
Not in practice, or practice disbarred	29	49	2	80
LEGITIMATE SAMPLE	399	1115	496	2010

Reasons given by the clients for the non applicability included a non involvement with quantity surveyors (a total of 183 responded in this manner), had limited dealings in the property field, while 67 respondents indicated that another division within their firm had answered the questionnaire. Reasons given by the architects were that they were too small to provide any meaningful response or, were not involved with quantity surveyors. Reasons given by the quantity surveyors were that they were too small, not involved with cost planning and cost control, or that they were more construction orientated than quantity surveying orientated.

5.1.3 CODING AND ANALYSIS OF DATA

The legitimate sample of returned questionnaires were coded manually and captured in data files to enable statistical computations to be made. Once the data were coded and captured in computer data files, the computer statistical package BMDP was used to analyse the collected data. Two programs contained in the BMDP suit of programs were used, one for general statistical information (BMDP 2D - detailed data description, including frequencies), and the other for histograms and cumulative frequencies (BMDP 5D - histograms and univariate plots).

5.2 ANALYSIS OF QUESTIONNAIRE SURVEY

For the sake of presentation, the relevant questions, together with the cumulative totals for each variable have been placed in the appendices at the back of this report, and hence, will not be duplicated in this chapter. However, reference will be made to the results obtained in the survey in order to show and present certain assertions.

The variable 'other' was included in the majority of questions for the purpose of providing the practitioner with an option of filling in their own variables. This variable has been removed form the questionnaire (unless otherwise stated in the analysis), as the quantity (all sample responses to the variable 'other' were under 5 percent) and quality of response provided was poor. Another reason for its exclusion was that if the 'other' variable was used, no written follow up was provided by the practitioner. Hence, no assessment of the variable could be made.

The option of 'not applicable' was used in certain of the questions. This option has been excluded from the results (unless otherwise stated in the analysis) in order to obtain a 'true' interpretation of the results. All responses, to which this exclusion applies, have been adjusted to take its exclusion into account. This was done in two steps. Firstly, the 'not applicable' responses were subtracted from the variable response, in order to get the new variable sample size. Secondly, the number of responses to the other options within the variable were divided into the new variable sample count in order to obtain the 'true' percentage response.

The rest of this chapter is devoted to the analysis of the results of the survey. Before the nature and treatment of uncertainty in construction price forecasting is dealt with, it is necessary to present an overview of the practice of price forecasting. This overview will be kept brief, as it is not within the scope of this thesis to present and critically examine the entire price forecasting process, but to examine the uncertainty associated therewith.

5.2.1 PRACTICE OF PRICE FORECASTING

In this section, the price forecasting models used by quantity surveyors will be presented under five sub-sections, namely, the models used to the make forecasts, the stage at which the afore mentioned models are utilised, the ability of the forecasting methods to model the building process, the accuracy obtained by the models and, lastly, factors which the practitioners feel affect the accuracy of the forecast.

a) Use of price forecasting models

For the purpose of presentation, it is felt that the results of the questionnaire survey are best conveyed with the aid of graphs, and hence will be used in conjunction with written explanations. Percentage responses will not be quoted in all the sub-sections that follow, unless found necessary, as these can be read off the graphs or from the attached appendices. Figure 5.1 and Figure 5.2 show the extent to which practitioners use forecasting models in the preparation of price forecasts.

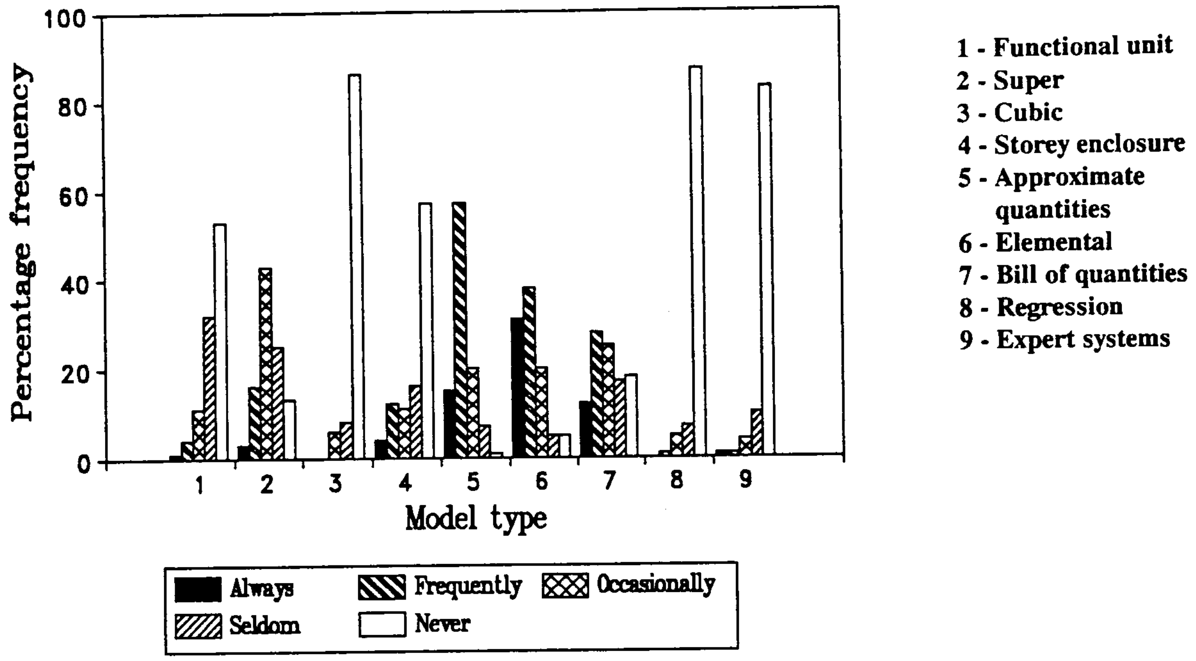

Fig 5.1 Use of forecasting models

It can be seen from Figure 5.1, that no single forecasting model is favoured by practitioners in their preparation of price forecasts. However, it can be said, if the 'always' and 'frequently' alternatives are added together, that the majority of respondents use the approximate quantities and elemental methods of price forecasting. The results indicate that above 50% of item respondents never use the functional unit or storey enclosure methods and over 80% of respondents never use the cubic, regression or expert system methods of forecasting. This, therefore, indicates that the super, approximate quantities, elemental and bill of quantities methods are, although with no regularity, used the most often to produce price forecasts.

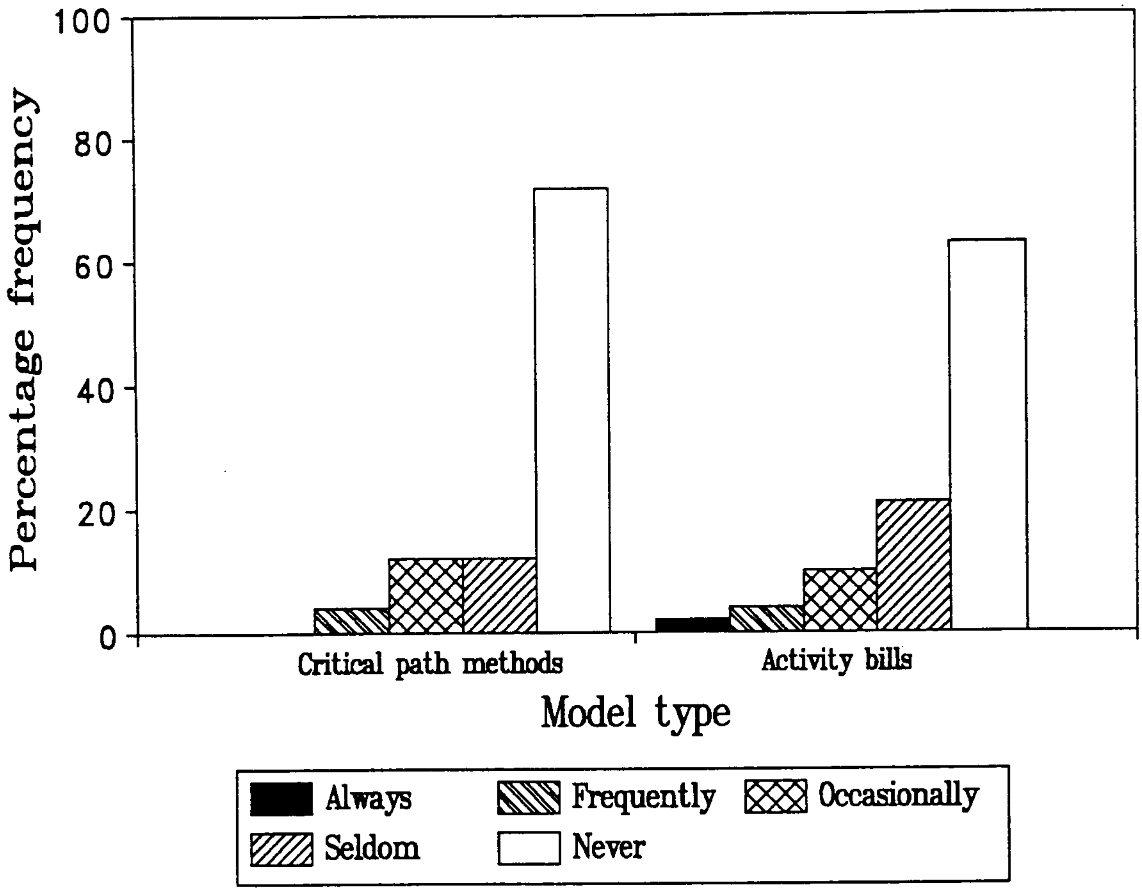

Fig. 5.2 Use of resource based forecasting models

Figure 5.2 indicates the use of two resource based methods of estimating. The results do not indicate a preference for the use of these two methods, as over 60% of respondents never use activity bills, and over 70% never use critical path methods.

b) Stage of model use

The models have been divided into three groups for the purpose of presenting the stage at which they are most frequently used. The groups are based on the results obtained from the previous section (*ie*. Use of price forecasting models). Group one includes the approximate quantities and elemental models, of which the majority of respondents indicated they use. Group two includes the super and bill of quantities methods of forecasting. Group three includes the functional unit, cubic, storey enclosure, regression and expert system form of price modelling, of which the majority of respondents indicated they never use.

Group one

It has been shown that the approximate quantities and elemental methods are the most frequently used forecasting models. According to the survey results, presented in Figure 5.3, the two methods are used with the same regularity by the majority of practitioners during the feasibility, sketch and detail design stages of the design process. From a similar study, conducted by Morrison (1983), it was found that the approximate quantities method of forecasting was favoured to that of the elemental method. The South African situation appears to favour the two methods equally.

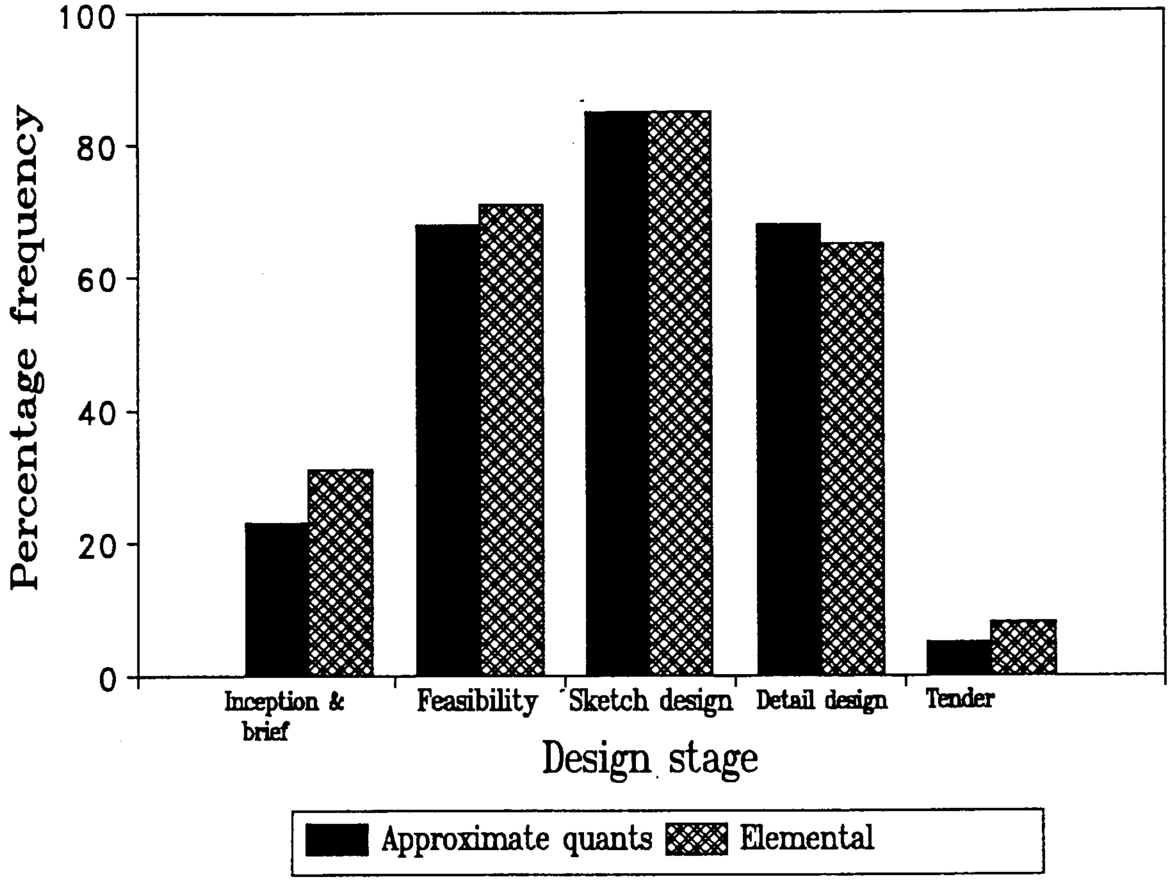

Fig. 5.3 Relationship between design stage and approximate quantities and elemental forecasting methods

Group two

It has been shown that the super and bill of quantities methods of forecasting are used by practitioners, but with less frequency than the approximate quantities and elemental methods. From Figure 5.4, it can be shown that the majority of respondents use the super method at the inception and brief stage and the bill of quantities method at the tender stage of design.

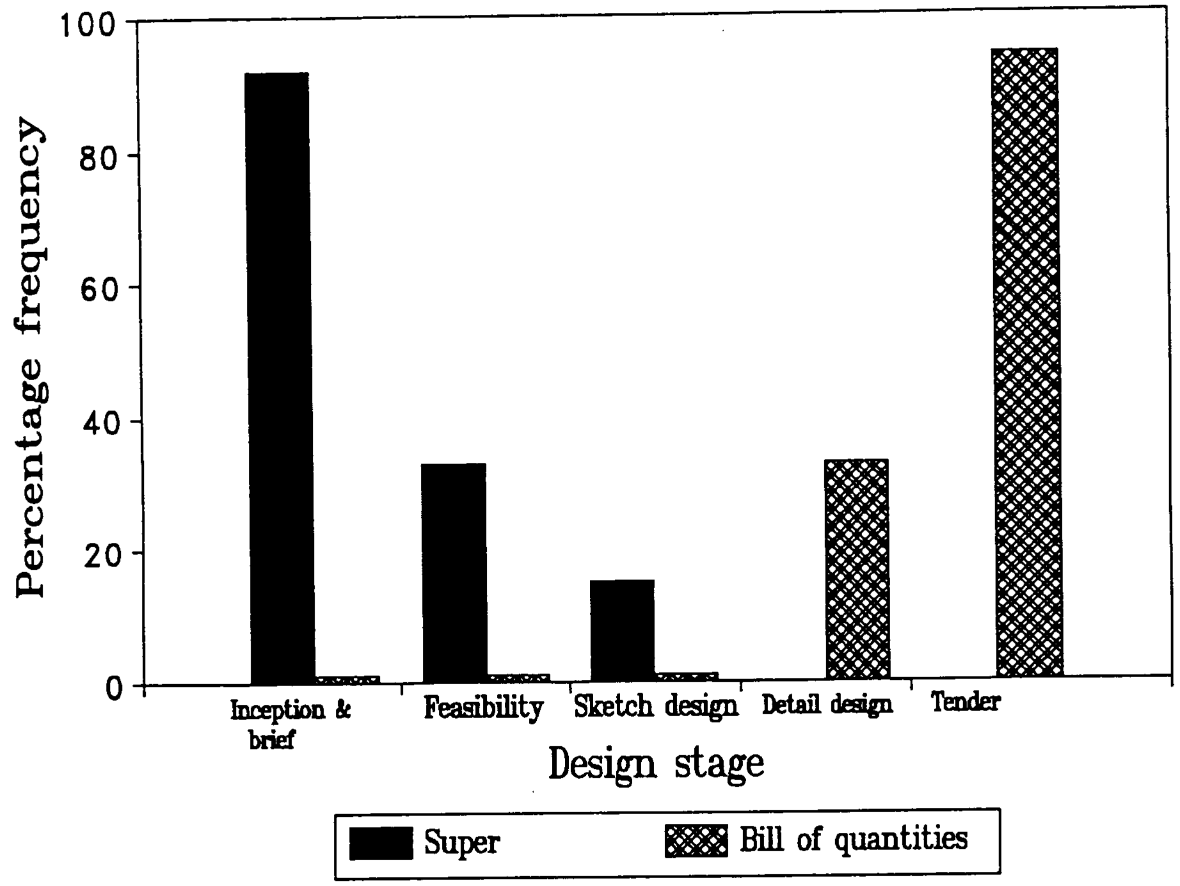

Fig. 5.4 Relationship between design stage and super and bill of quantities forecasting methods

Group three

The functional unit, cubic, storey enclosure, regression and expert systems methods of forecasting have been included in this group as it was indicated from the results (Figure 5.1) that the majority of respondents never use these methods. The responses (Figure 5.5) for the cubic, regression and expert systems methods are slightly misleading, as the responses to these variables were only 6, 5 and 10 respectively. A possible reason for these low responses, could be assigned to a dislike for the methods, as it can be ascertained from Figure 5.1 that over 80% of respondents never use the cubic, regression or expert system methods of forecasting. It is however believed that the lack of use of expert systems could be ascribed to a possible scarcity of knowledge about the methods on the part of practitioners, as few expert system models are currently available for use as forecasting models.

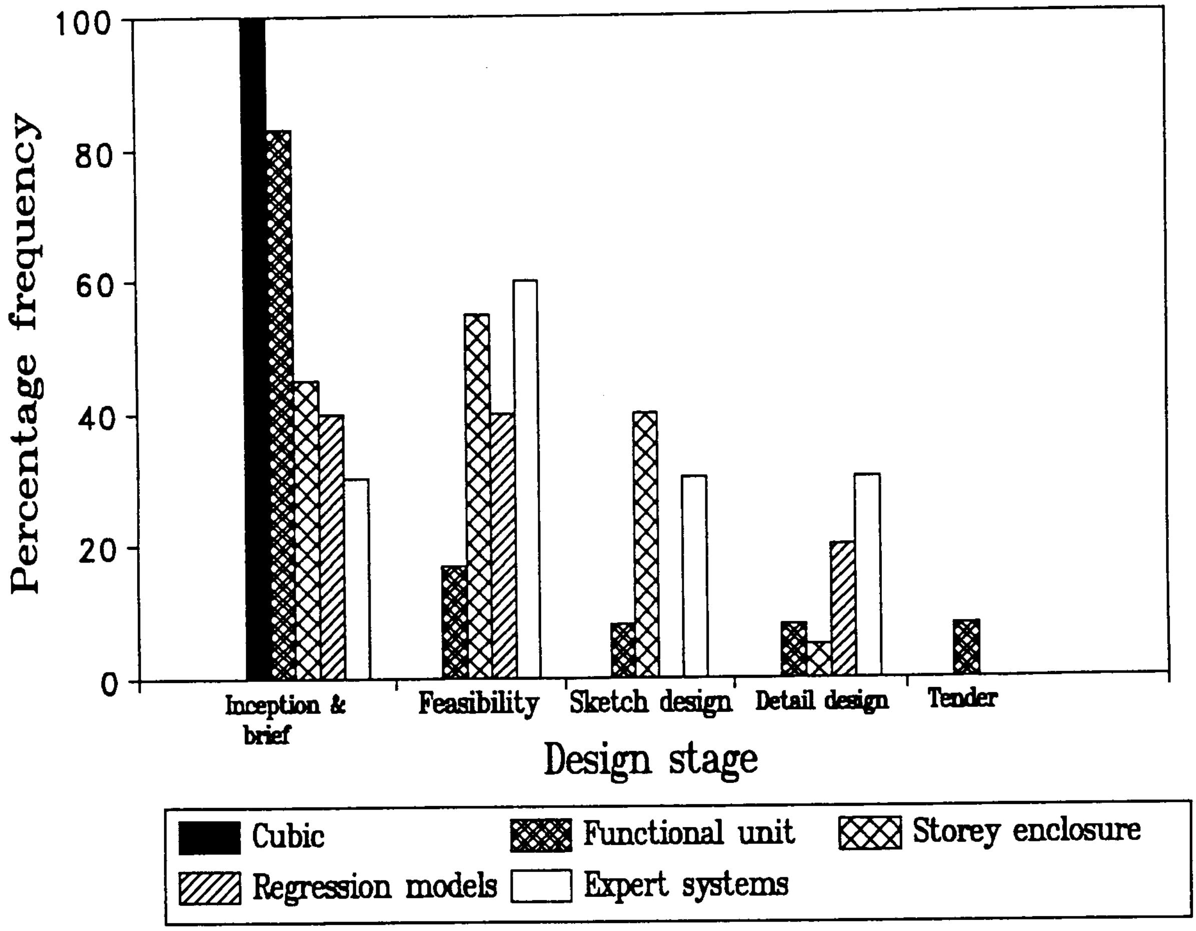

Fig. 5.5 Relationship between design stage and functional unit, cubic, storey enclosure, regression models and expert systems forecasting methods

From the above results it can be concluded that practitioners have a preference for a particular forecasting model during the stages of design. This preference is summarised in Table 5.5.

Table 5.5 Stage of model use

STAGE	FORECASTING MODEL PREFERENCE
Inception & brief	Super method
Feasibility	Approximate quantities and Elemental
Sketch design	Approximate quantities and Elemental
Detail design	Approximate quantities and Elemental
Tender	Bill of quantities

c) Ability of forecasting methods to 'model' the building process

The extent to which quantity surveyors feel that the forecasting methods are capable of modelling the building process, is represented graphically in Figure 5.6.

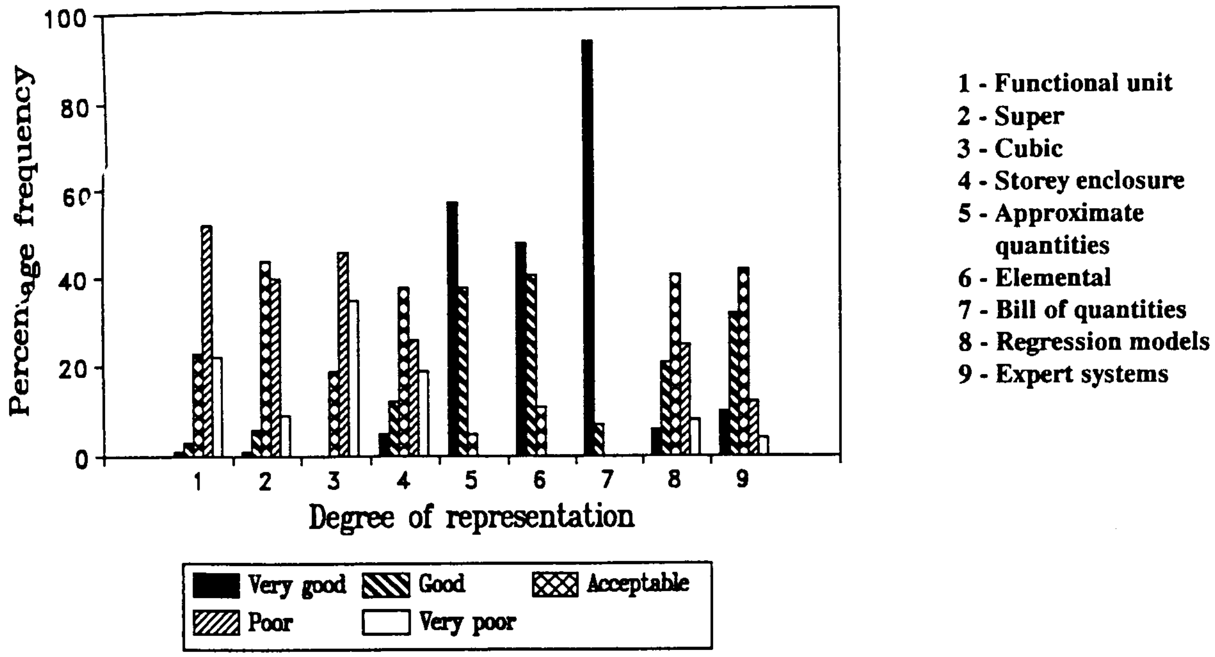

Fig. 5.6 Model representation of the building process

Table 5.6 has been compiled to show the mode (the value of greatest frequency) and median of the respondents answers.

Table 5.6 Ability to model the building process

	MODE	MEDIAN
Functional unit	poor	poor
Super	acceptable	acceptable
Cubic	poor	poor
Storey enclosure	acceptable	acceptable
Approximate quantities	very good	very good
Elemental	very good	good
Bill of quantities	very good	very good
Regression models	acceptable	acceptable
Expert systems	acceptable	acceptable

From Table 5.6, it is apparent that practitioners feel the approximate quantities, elemental and bill of quantities methods of forecasting are capable of modelling the building process. This could be a reason for the popularity of the methods, as indicated above. It has been noted that the majority of practitioners start using the approximate quantities and elemental forecasting methods at the feasibility stage of the design process. It is therefore implied that none of the methods utilised during the inception and brief stages are good, or capable enough of modelling the building process.

d) Accuracy of forecasting methods

Table 5.7 and Figure 5.7 give the expected accuracy levels of the price forecasting models. The table is arranged in order of mean accuracy for the purpose of presentation.

Table 5.7 Ranges of expected model accuracy

	EXPECTED ACCURACY RANGES 0 - 5%	6% - 10%	11% - 15%	16% - 20%	21% - 25%	above 25%	Mean	Respondents
Bill of quantities	92	8	0	0	0	0	4	(85)
Approximate quantities	55	36	5	4	0	0	8	(83)
Elemental	49	43	5	3	0	0	8	(83)
Storey enclosure	11	40	34	3	0	12	14	(35)
Super	0	34	34	20	3	9	16	(76)
Expert systems	13	31	25	25	6	6	16	(16)
Regression	0	40	27	27	0	13	18	(15)
Cubic	0	21	37	16	0	26	20	(19)
Functional unit	0	17	31	24	7	21	20	(29)

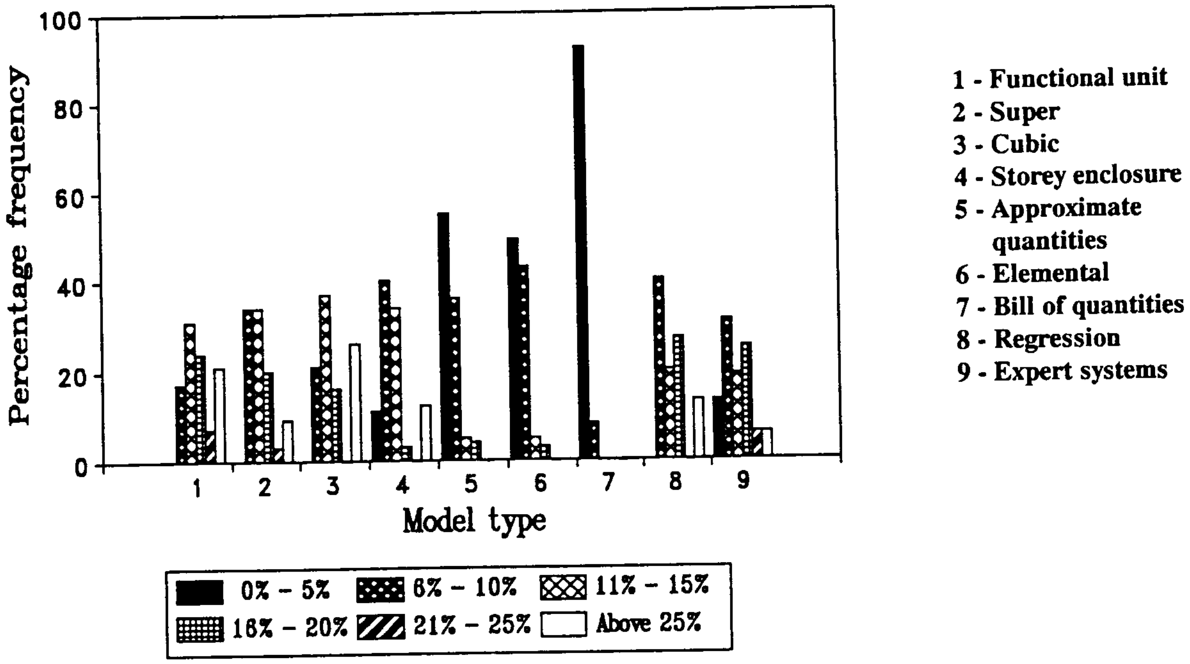

Fig. 5.7 Accuracy of forecasting models

From the results of the question pertaining to the stage of model use, it was concluded that practitioners had a preference for the use of the super method of forecasting during the inception and brief stage of design. During the feasibility, sketch and detail design stages, a preference for the approximate quantities and elemental methods of forecasting was indicated and, during the tender stage, the bill of quantities was favoured.

From these preferences, it can be said that the expected forecast accuracy would be within 16% of the expected tender figure during the inception and brief stage, within 8% during the feasibility, sketch and detail design stage and, within 5% during the tender stage.

The accuracy levels of the forecast, as indicated by practitioners, at the various stages of the project relative to the accepted tender, is presented in Figure 5.8.

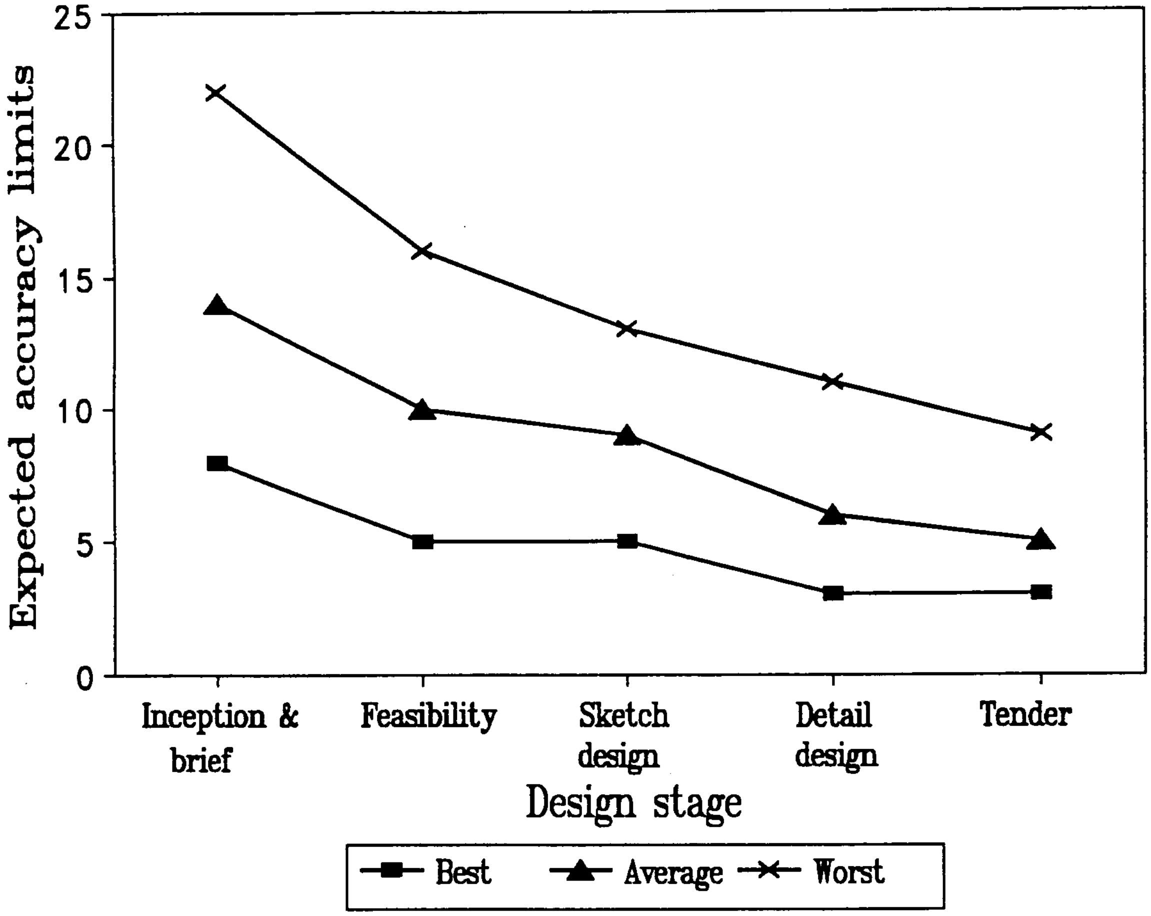

Fig. 5.8 Accuracy of forecast at the different stages of design

From the results obtained from Table 5.7 and Figure 5.8, it can be said that the average accuracy, as offered by practitioners, is the likely expected accuracy of the forecast at the various stages of design.

e) Factors influencing forecast accuracy

Six factors that could affect the accuracy of the forecast were suggested in the questionnaire. These factors, together with the responses from practitioners is presented in Figure 5.9. Although the option 'other' was included with the question, no other factors influencing the accuracy of the forecast were offered by respondents. If the totals of the options 'always' and 'frequently' are summed, over 80% of item respondents state that the availability of information, expertise, the modelling method used and the presence of a good data base are the factors that affect the accuracy of the forecast the most.

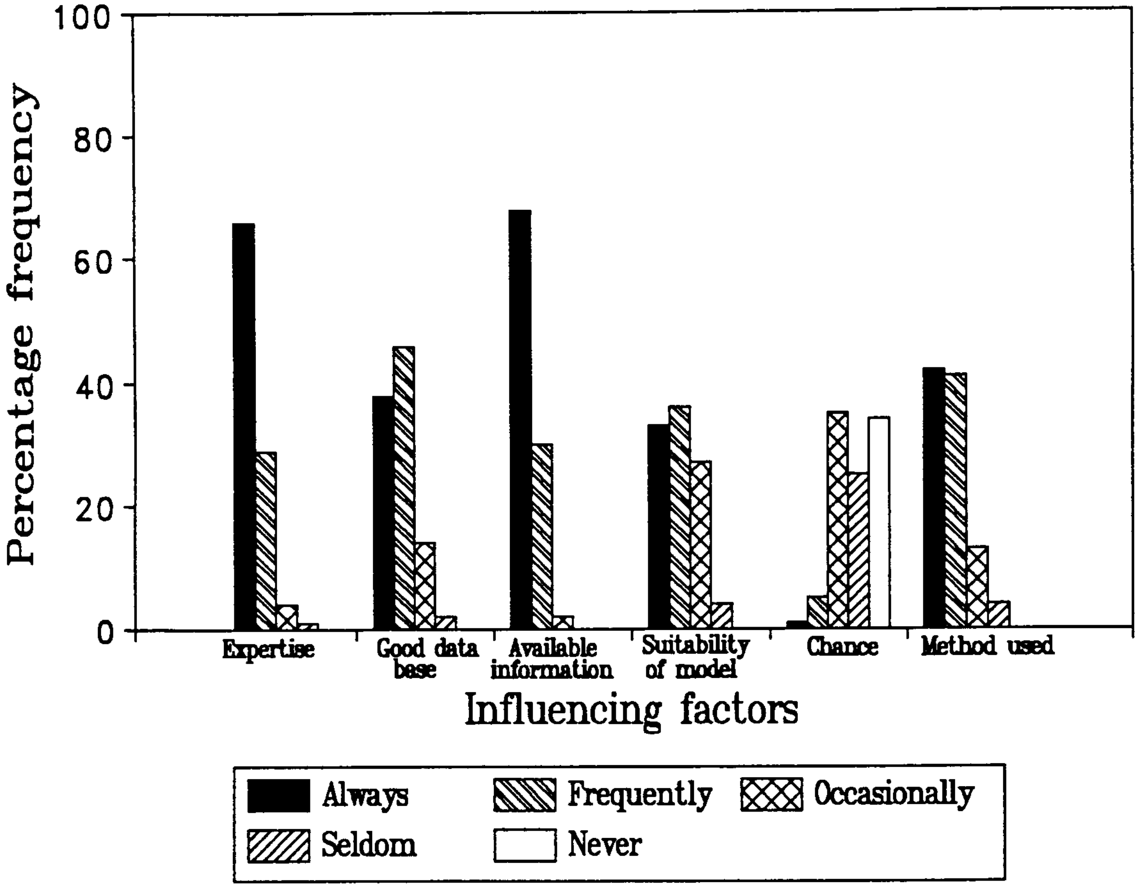

Fig. 5.9 Factors influencing forecast accuracy

It has been shown that the expertise of the forecaster, the variability of data, the availability of design information and, the suitability of the forecasting method are factors that do lead to uncertainty in the design process. It is therefore inferred that if the uncertainty in these factors could be controlled, the accuracy of the forecast could be improved.

5.2.2 USE OF DATA

The use of data is an essential element of the price forecasting process. This section is dealt with under three sub-sections, namely, the forms of data kept by quantity surveying firms, the quantity surveyors preference of data type and, the sources of data that are used in the price forecast.

a) Forms of data kept by firms

Table 5.8 indicates four forms of data kept by quantity surveying firms. The four forms of data kept by the majority of offices, namely, cost analyses, updated bills, price books and specialist quotes are all vulnerable to the subjectivity associated in their build up. This subjectivity in the data transformation has been dealt with in Chapter Two, and will therefore not be repeated here.

Table 5.8 Forms of data kept by firms

FORMS OF DATA	KEPT
Cost analysis	87%
Updated bills	89%
Price books (eg. Merkels)	64%
Specialist quotes	86%

b) Preference for data use in forecasts

The stacked bar graph presented in Figure 5.10 represents the first, second and third choices of data that practitioners prefer to use for the preparation of price forecasts.

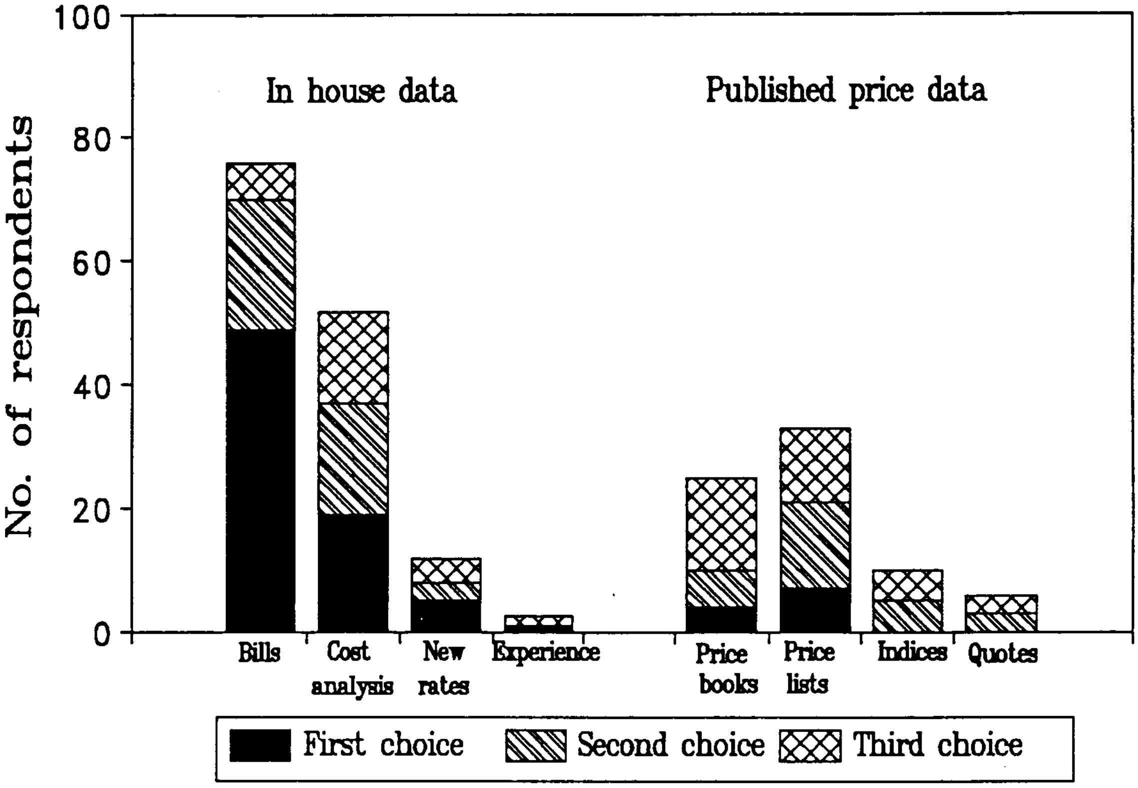

Fig. 5.10 Preference of forecasting data

The results indicate that in-house data is preferred to that of published price data, with ‘previously priced bills’ and ‘cost analyses’ being the most preferred form of in-house data. The rates obtained from these two forms of data are subject to the uncertainties associated with the variability of trades, the variability of individual bill items, as well as the updating of individual rates or the entire forecast by means of indices.

c) Sources of data used for forecasting methods

It is clearly apparent from Table 5.9 that practitioners prefer to use in-house data for the forecasting models. The option ‘other’ has been included to indicate that practitioners feel that the three options of in-house data, published price books and specialist quotes, are the three main sources of data used for producing their forecasts.

Table 5.9 Sources of data used in price forecasting models

MODEL	IN-HOUSE DATA	PUBLISHED PRICE BOOKS	SPECIALIST QUOTES	OTHER
Functional unit	87%	13%	20%	0%
Super	97%	5%	11%	1%
Cubic	88%	0%	13%	0%
Storey enclosure	86%	0%	21%	5%
Approximate quantities	100%	30%	52%	0%
Elemental	99%	24%	51%	3%
Bills of quantities	94%	26%	60%	3%
Regression models	75%	0%	13%	3%
Expert systems	50%	0%	50%	3%

5.2.3 PRESENCE OF UNCERTAINTY IN THE PRICE FORECASTING PROCESS

Having presented a brief overview of the practice of price forecasting, the question of the uncertainty associated therewith will now be addressed. This has been covered in two sub-sections. Firstly, the presence of uncertainty within the price forecasting process is addressed, and secondly, the ways in which practitioners treat the uncertainty in the afore mentioned sub-section.

In this, the first of the two sections, the uncertainty in the communication of cost advice, the uncertainty in design information, the uncertainty in cost data and, the uncertainty via the distortion of data will be presented.

The option of ‘very high’ and‘ high’ have been extracted (unless otherwise stated) from the options available to respondents in order to ascertain whether the factors listed below are felt, by practitioners, to be of any significance.

a) Uncertainty in the communication of cost advice

The issue of communication, as it is dealt with here, concerns the perceptions that the different members of the design team have in respect of the transfer of cost related information (for example, a single figure forecast presented by the quantity surveyor). It is an important issue, for if the information passed on from the architect to the quantity surveyor is not understood and communicated correctly, confusion may arise, resulting in uncertainty.

As shown in Figure 5.11, 89% of the respondents indicated an unacceptably high presence of uncertainty in the communication of cost related issues during the inception and brief stage of design. This cumulative percentage drops to 60% during the feasibility stage, and to 32% during the sketch design stage.

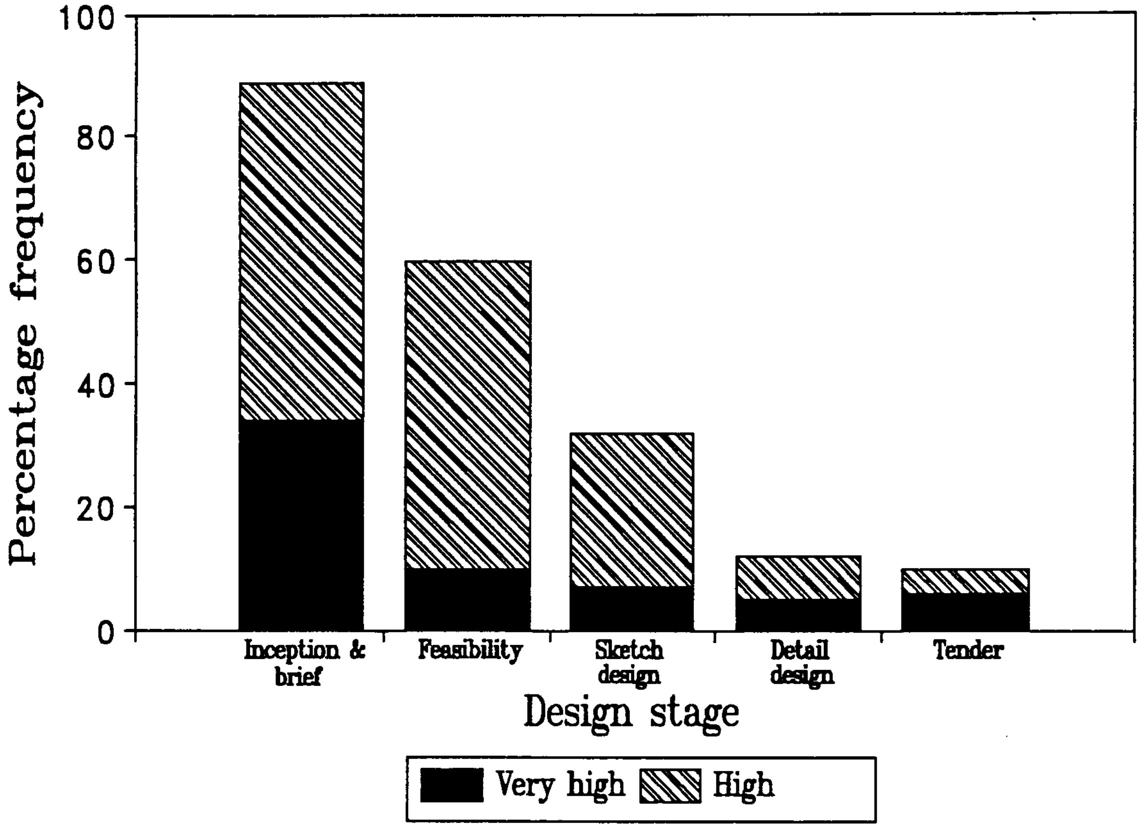

Fig. 5.11 Presence of uncertainty in the communication of cost advice

It can therefore be said that the majority of respondents feel that the communication of cost related issue between the members of the design team is unacceptable up to some period in the sketch design stage. This figure is alarming, as up to 80% of cost of the project is already determined by the sketch design stage, making the quantity surveyors task of controlling the price limit of the project, extremely difficult.

b) Uncertainty in design information

Figure 5.12 indicates that 85% of quantity surveyors state that the design information, provided by the architect, is unacceptable during the inception and brief stage of design.

During the feasibility stage this percentage drops to 72% with a further drop to 45% during the sketch design stage.

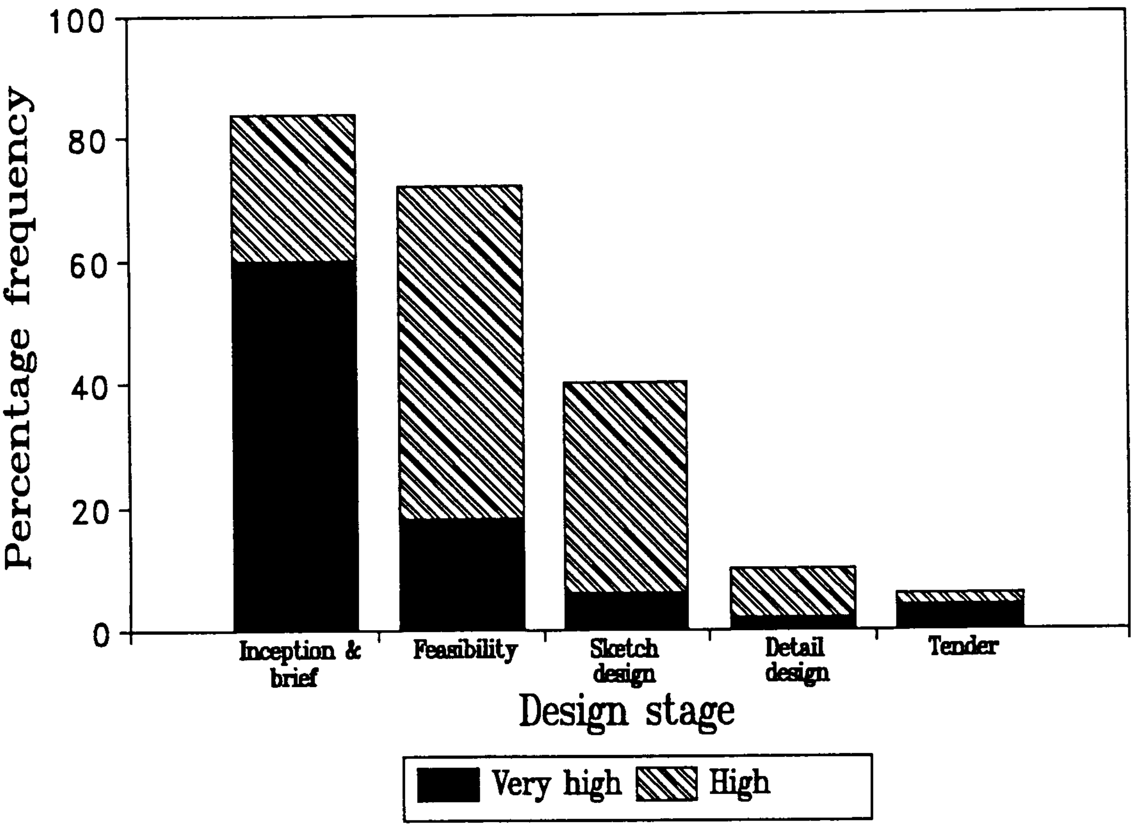

Fig. 5.12 Uncertainty in design information

The presentation of a price forecast is dependant upon the information provided by the architect and/or design team during the various stages of design. The above mentioned percentages indicate that the majority of quantity surveyors feel that no 'accurate' price forecast can be made (unless this uncertainty is provided for in some manner) until some time in the sketch design stage.

c) Uncertainty in cost data

It has already been shown that data is essential to the price forecasting process. If the accuracy of this data is not known with relative certainty, it follows that the entire forecast will be filled with uncertainty. Figure 5.13 indicates the extent to which quantity surveyors feel that the data, used in their forecasts is uncertain.

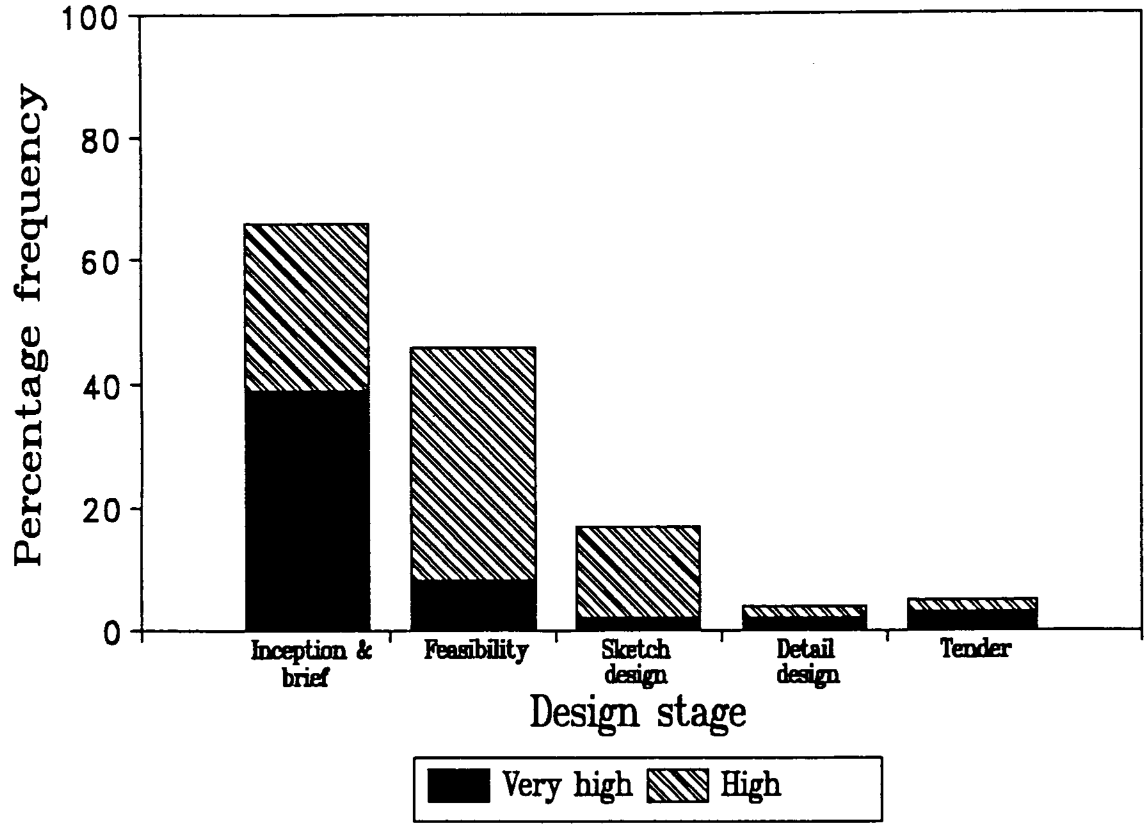

Fig. 5.13 Uncertainty in data

It is noted that 65% of practitioners feel that the presence of uncertainty in the data they use during the inception and brief stage of design is unacceptably high. This percentage drops to 45% during the feasibility stage and to 17% during the sketch design stage.

d) Uncertainty via the distortion of data

A possible cause of the uncertainty present in data is the manner in which the data were originally obtained. It has been shown that there is a preference for the use of in-house data above that of published price data. The two forms of in-house data most preferred by practitioners are bills of quantities and cost analyses, while the most preferred forms of published price data are price books and price lists.

The four preferred forms of data are graphically depicted in Figure 5.14, where practitioners have indicated the extent to which they feel that the forms of data are 'distorted' by the time they reach their final format. This distortion refers to the data transformations (Raftery, 1984) discussed in Chapter Two.

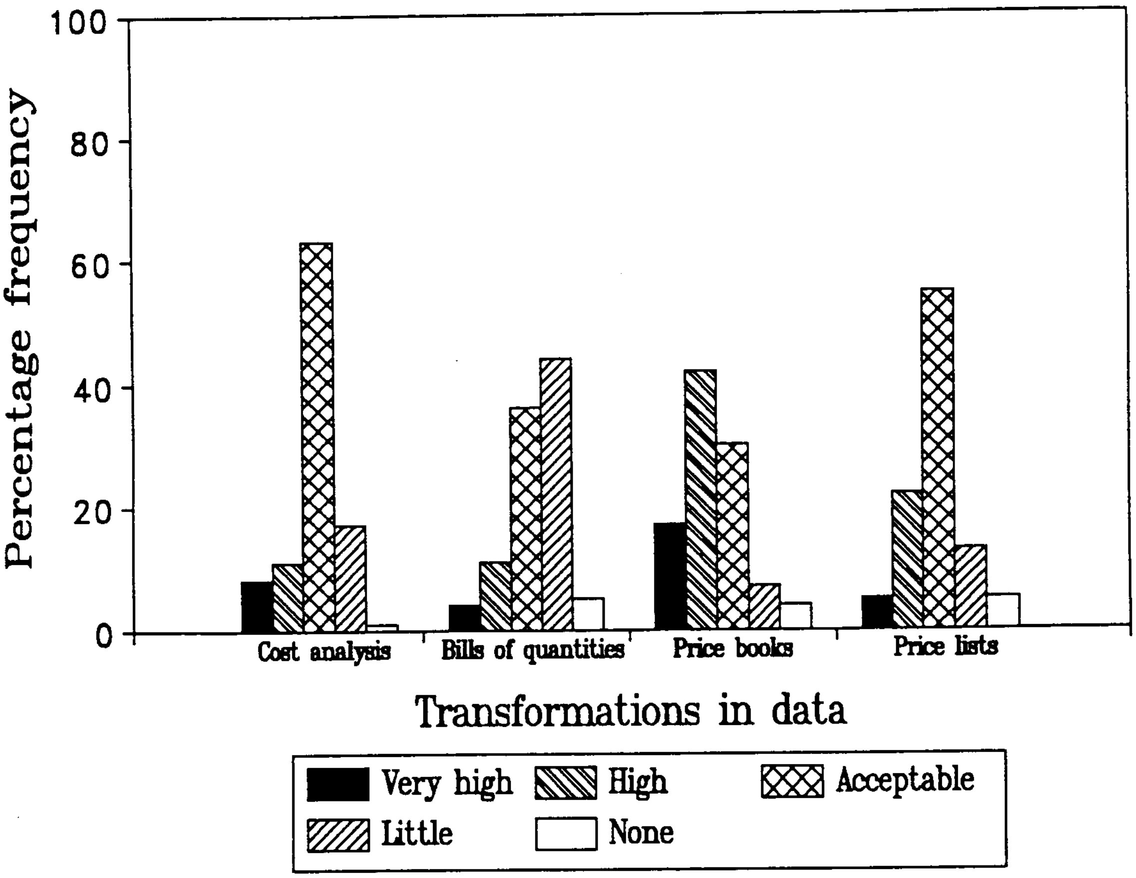

Fig. 5.14 Distortion of data

If the percentage totals of the options 'very high' and 'high' provided to respondents are added together, it can be shown that the distortion of price books and price lists is 59% and 27% respectively. These results may be a reason for their low use by quantity surveyors.

5.2.4 TREATMENT OF UNCERTAINTY

It has been already been shown that the presence of uncertainty, especially from the start of the design process to some period within the sketch design stage, exists in the price forecasting process. The purpose of this section is to show the extent to which quantity surveyors adjust their price forecasts, in order to make provision for this uncertainty.

In this section, the factors that influence the degree to which uncertainty is provided for, the ability of the forecasting models to handle the different types of uncertainty, the techniques used for the treatment of uncertainty, and the stages in which these techniques are implemented, will be presented.

a) Factors influencing the provision of uncertainty in cost advice

Seven factors to which the respondents could answer with varying degrees of belief were presented in the questionnaire survey. This was done in order to determine the factors that influence whether or not uncertainty is taken into account in the provision of cost advice. These factors include, the cost of the project, a lack of expertise on the part of the forecaster, the size of the project, the type of client (eg. public sector client), the financial costs to the quantity surveyor, client sophistication, and the time available in which to make the forecast.

Results of the variable 'other' indicate that only one additional factor was added to the above list. Although the single respondent indicated that the factor frequently influenced whether or not he takes uncertainty into account in the provision of cost advice, he did not indicate what the factor was. It is therefore inferred that the seven suggested items are the main factors influencing the treatment of uncertainty.

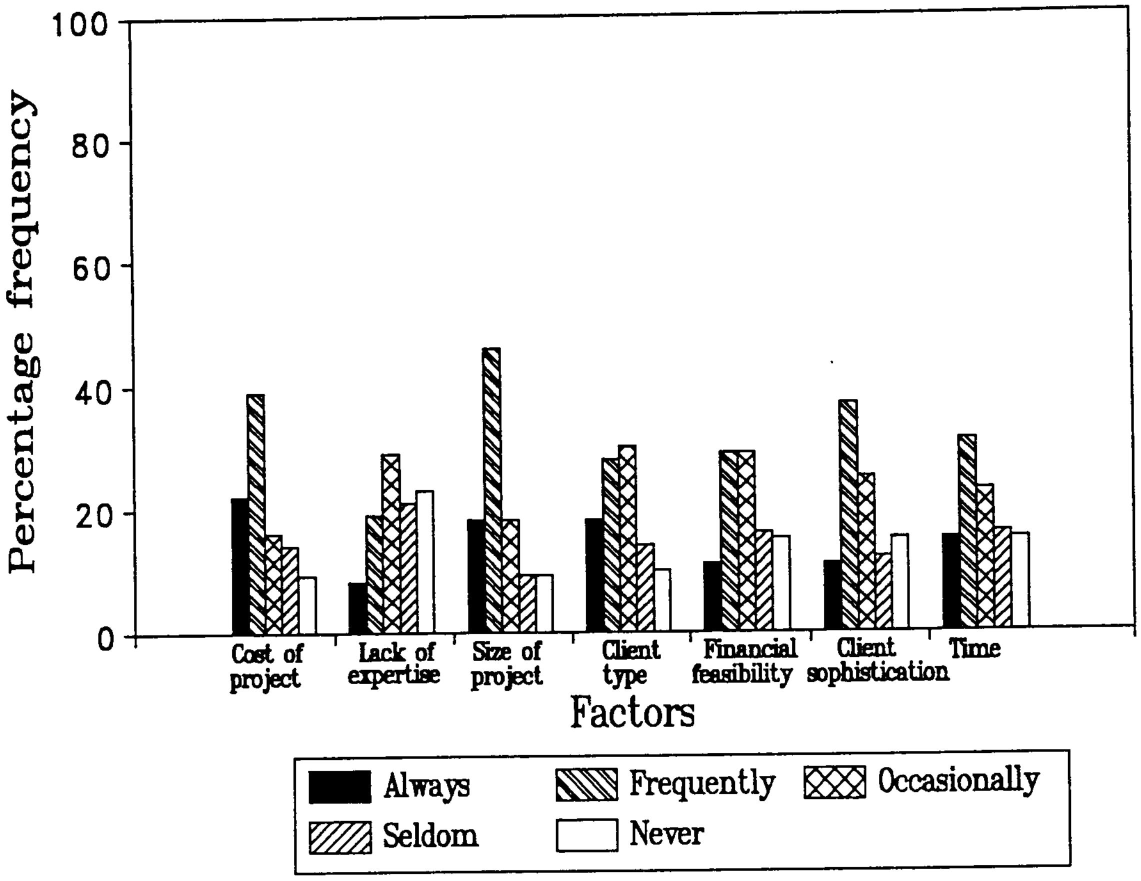

Fig. 5.15 Factors influencing the treatment of uncertainty

From the results of this question, which are presented in Figure 5.15, it appears that all factors have significance in influencing whether or not uncertainty is taken into account. A possible exception could be the lack of experience factor, as 44% of respondent indicated that this factor 'never' or 'seldom' influences their decision.

b) Ability of forecasting models to handle uncertainty

From the results of the practitioners assessment for the potential of price forecasting methods to handle uncertainty (Appendix 1, question 5.2), it is possible to rank the price models' ability to handle uncertainty. In order to perform this ranking, the **actual** assessment of practitioners was needed, hence, the exclusion of the variable 'don't know'. The responses were then adjusted in the same manner as explained in section 5.2, with the results being presented in Table 5.10.

Table 5.10 Potential of forecasting models to handling uncertainty

	(1) very good	(2) good	(3) accept-able	(4) poor	(5) very poor	
Functional unit	4%	0%	22%	44%	30%	(64)
Super	2%	7%	31%	46%	14%	(93)
Cubic	0%	4%	11%	44%	41%	(66)
Storey enclosure	3%	16%	37%	30%	14%	(73)
Approximate quantities	29%	46%	24%	1%	0%	(91)
Elemental	27%	57%	13%	3%	0%	(94)
Bill of quantities	75%	20%	3%	1%	1%	(94)
Regression models	8%	12%	33%	39%	8%	(36)
Expert systems	9%	17%	48%	17%	9%	(35)

In order to calculate the ranking, the sum of the option 'very good', 'very good and good' and 'very good, good and acceptable' were added together and ranked individually. These three rankings were then added together and divided by three to get the final ranking of quantity surveyors assessment for the models ability to handle uncertainty. The result are shown in Table 5.9.

Table 5.11 Ranking of models ability to handle uncertainty

	A Option 1	RANK	B Option 1 & 2	RANK	C Option 1 & 2 & 3	RANK	TOTAL A+B+C	FINAL RANKING
Bill of quantities	75%	1	95%	1	98%	2	4	1
Approximate quantities	29%	2	75%	3	99%	1	6	2
Elemental	27%	3	84%	2	97%	3	8	3
Expert systems	9%	4	26%	4	74%	4	12	4
Regression models	8%	5	20%	6	55%	6	17	5
Storey enclosure	3%	7	19%	5	56%	5	17	6
Functional unit	4%	6	4%	8	26%	8	22	7
Super	2%	8	9%	7	40%	7	22	8
Cubic	0%	9	4%	9	15%	9	27	9

It is apparent from the ranking that bills of quantities are felt to handle uncertainty better than any of the other models presented. However, although ranked first, the results indicate little difference between the bill of quantities, approximate quantities and the elemental methods of forecasting, with regards to their ability to handle uncertainty.

It is interesting to note that the lower down the model is on the rating list, the earlier it is applied in the forecasting process, implying that forecasts made in the early stages of the design process, are associated with an unacceptable degree of certainty. For example, it has been shown that the super method of forecasting is most frequently used during the inception and brief stage of design. However, it is ranked second lowest, confirming the high degree of uncertainty associated with this stage of design.

c) Techniques used for the treatment of uncertainty

Ten techniques of treating uncertainty, along with the variable 'other', were included in this question. Three of the original ten variables, namely maximum/minimum ranges, payoff tables and risk analysis, have been excluded, as these have not been dealt with under Chapter Four of this thesis. The exclusion of payoff tables has no significant consequences on the overall results, as 87% of respondents indicated that they never use the technique. Risk analysis has been excluded, for as mentioned in the introduction, the terms 'risk' and 'uncertainty' have different definitions, with the prior having no relevance to this report. However, the response has been included in appendix I, for the purpose of reference.

Although not included in Figure 5.16, the option 'other' indicated that no other techniques of treating uncertainty were communicated by respondents.

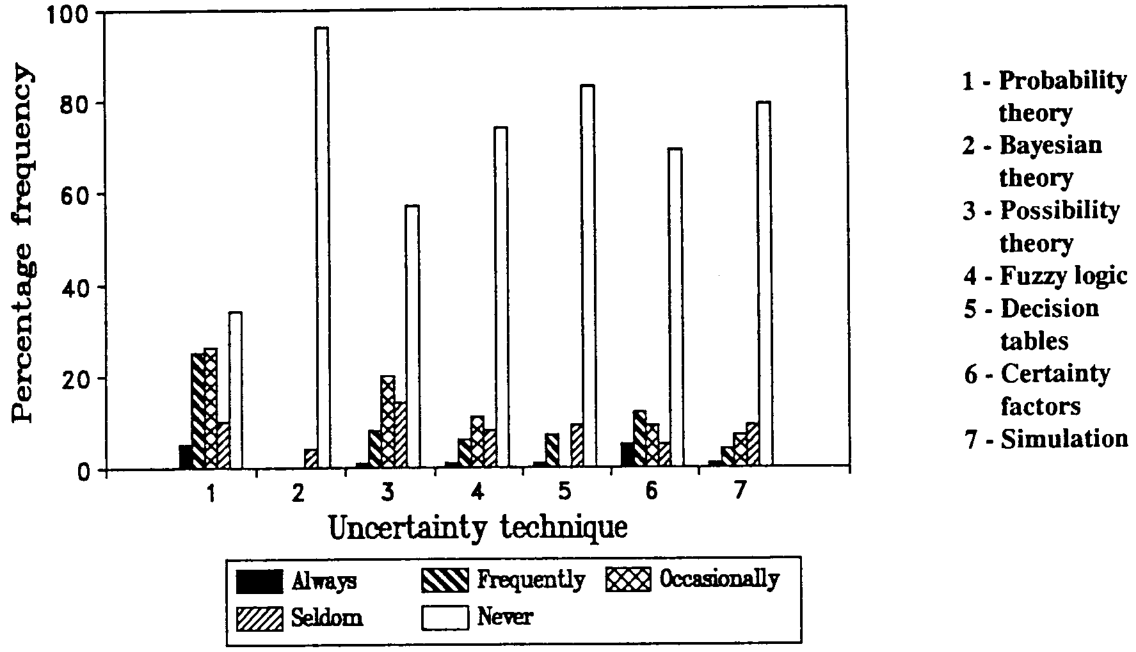

Fig. 5.16 Techniques used for the treatment of uncertainty

The results, presented graphically in Figure 5.16, indicate that the majority of practitioners never use bayesian theory, fuzzy logic, decision tables, certainty factors, or techniques of simulation for the treatment of the uncertainty associated with price forecasts. It can therefore be inferred that probability theory, possibility theory, and maximum/minimum ranges are the techniques that are most often used by quantity surveyors, for the treatment of uncertainty. The use of maximum/minimum ranges is not considered to be a technique for handling uncertainty, but rather a means of communicating the presence of uncertainty.

It has been shown that the forecasting process does have an element of uncertainty attached to it, although, by studying the results of this question, it can be seen that little provision is allowed for the treatment thereof.

d) Stages of uncertainty technique implementation

It was concluded that probability and possibility theory were the techniques that are most frequently used by quantity surveyors for the treatment of uncertainty. It can be seen from Figure 5.17 that the greatest use for these techniques is made during the inception and brief, and feasibility stages of the design process.

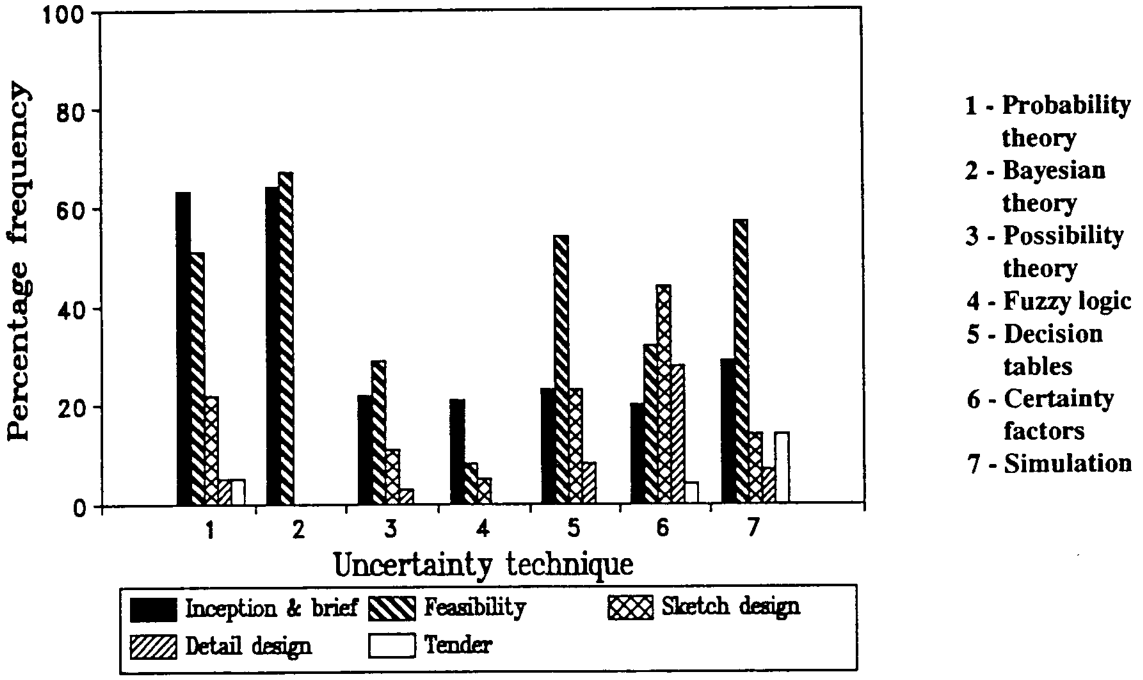

Fig. 5.17 Stage of uncertainty technique implementation

It is felt that the results used to indicate at which stage the uncertainty techniques are implemented are not truly representative as the sample sizes from which the results are obtained, is very small. For example, the number of responses received for the bayesian heory, fuzzy logic, decision tables and simulation techniques were 3, 19, 13 and 14 espectively.

5.2.5 THE COMMUNICATION OF UNCERTAINTY

The different types of uncertainty associated with the price forecasting process and the techniques used by quantity surveyors to treat this uncertainty have been presented above. From the above analysis, it has been concluded that little provision is allowed by the quantity surveyor for the treatment of uncertainty.

The objective of this section is threefold. Firstly, to see if, in the opinion of the client and architect, the presence of uncertainty of cost-related issues is acknowledged by the quantity surveyor. Secondly, to see if any of the uncertainty techniques presented above are used by the quantity surveyor to quantify the presence of uncertainty to the client or architect, and thirdly, to show the manner used by the quantity surveyor to communicate uncertain information.

a) Acknowledgement of uncertainty

According to the results obtained from the client and architect questionnaire survey, 86% of both architect and client respondents indicated that the presence of uncertainty is acknowledged by the quantity surveyor. Furthermore, it was indicated by 93% of the architect respondents that the nature of the uncertainty was communicated to them by the quantity surveyor. It appears that this advice is given pro-actively by the quantity surveyor as, according to the results obtained from the quantity surveyors survey, only 50% of the client respondents and 40% of the architect respondents ask for an assessment of the uncertainty associated with cost advice.

b) Uncertainty techniques received by the architect and client

The responses to the above question, illustrated in Figure 5.18 and Figure 5.19, has been included to ascertain whether the techniques used by the quantity surveyor to treat uncertainty are in fact received by the architect and client. Dealing with the two parties in turn, it appears that probability theory is received by the majority of architects.

From the responses of the client questionnaire survey, it is apparent that the majority of respondents have the presence of uncertainty conveyed to them by means of decision tables and probability theory. The results indicate that 66% of clients always receive and, 23% frequently receive any presence of uncertainty by means of decision tables.

It is clear, from both Figure 5.18 and Figure 5.19, that bayesian theory, possibility theory, fuzzy logic and simulation are not used with any regularity to convey the presence of uncertainty to the architect and clients. This statement can be proved true when compared against the results provided by the quantity surveyors.

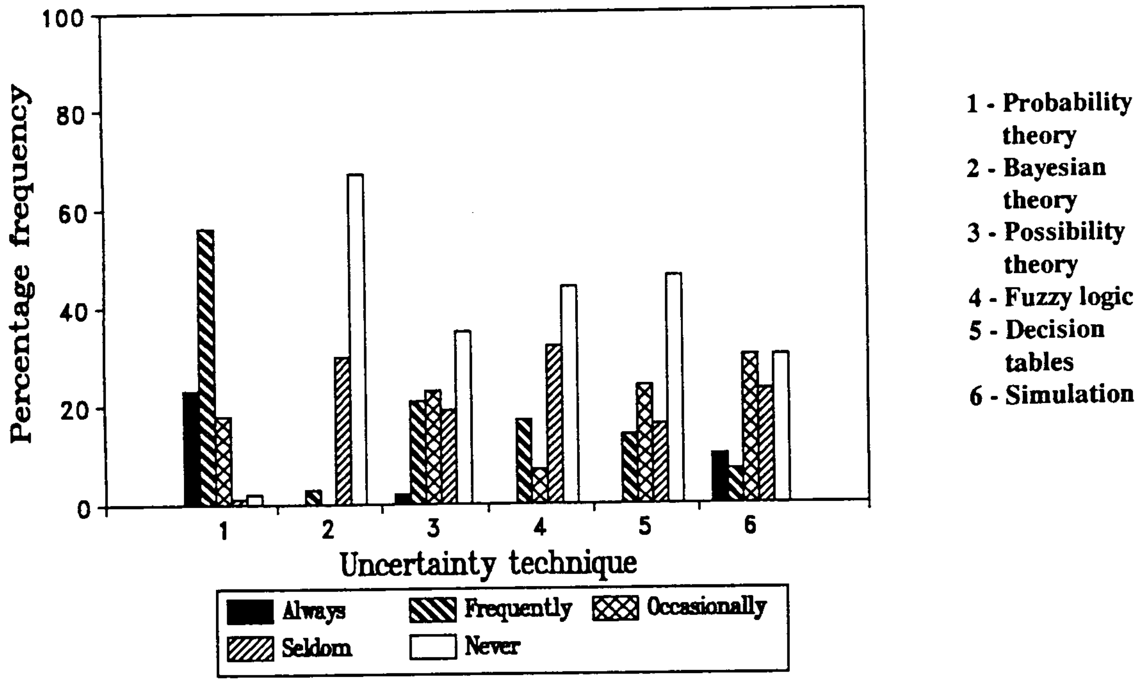

Fig. 5.18 Uncertainty techniques received by architects

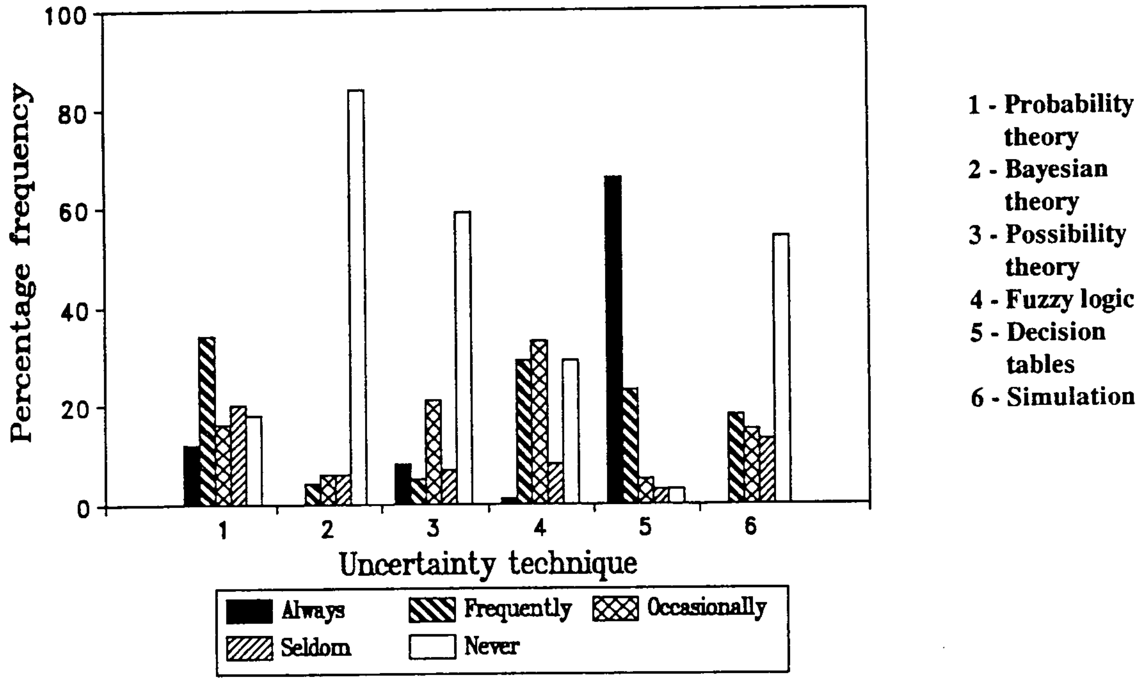

Fig. 5.19 Uncertainty techniques received by clients

:) Communication of uncertain information

Figure 5.18 represents a summary of the methods used by quantity surveyors to convey uncertain information. A data sample of 63 respondents was used to analyse this question. Because the output was presented in a written format, the actual written replies will not be found in the appendix with the rest of the coded questions. The pie labeled others, representing six respondents, includes replies such as gives a percentage allowance, a risk analysis of uncertain variables is undertaken, a feasibility study of uncertain variables is undertaken, a graphic representation and, only communicates if requested.

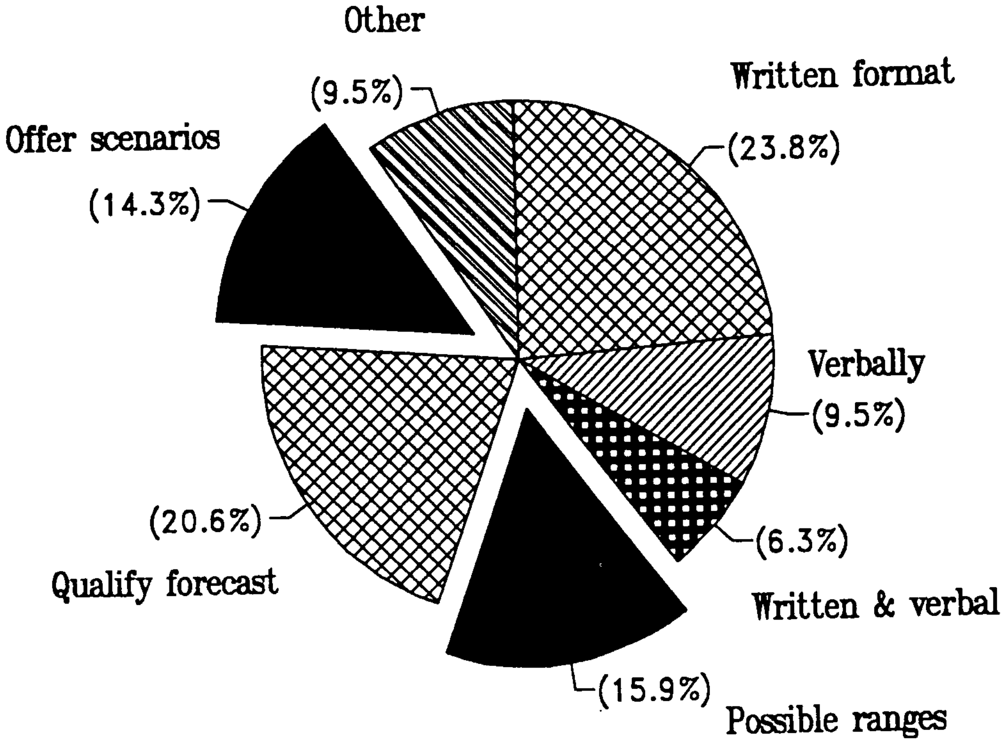

Fig. 5.20 Communication of uncertain information

As can be seen by the exploded pies, 30% of the respondent offer a quantitative (or alternative solution) response in a verbal manner, in an attempt to explain the nature of the uncertainty. It is assumed from the responses that this percentage group offers a meaningful way of presenting uncertainty as two way communication is taking place, and therefore, the intended meaning of the sender is 'shared' rather than stated. Of the 21% of respondents who qualify the forecast, and the 24% of respondents who present uncertain information in a written format, it is impossible to ascertain whether the users have understood what has been stated, and hence this manner of communicating uncertainty could be ineffective.

In order to improve the communication of uncertain information within price models, the forecasting models need to loose their 'black box' image (Amkreutz, 1976; Ferry and Brandon, 1991) in order to be more easily understood by all users.

Although the results obtained from the survey have not been discussed comprehensively, it is apparent that a high degree of uncertainty is present within the price forecasting process. It has also been concluded that practitioners make little allowance for this uncertainty.

In the following chapter, a possible method for improving the problem of uncertainty within the price forecasting process is presented, discussed and analysed.

CHAPTER 6

PROPOSED MODEL FOR INCORPORATING, EVALUATING AND COMMUNICATING UNCERTAINTY IN BUILDING PRICE FORECASTING

6.1 INTRODUCTION

It is not the intention of this report to provide a system or technique that will completely revolutionise forecasting (this would be overly ambitious, and possibly unrealistic (Brandon, 1987)), but it is intended to present the reader with a modelling environment that is superior to existing price forecasting models. This modelling environment will take the form of an expert system.

Brandon *et al.* (1988), in evaluating the expertise and ability of a forecaster to produce a forecast, list five criteria as being the knowledge of measurement rules, prevailing market, design and client needs, the relationship between design features and production resources and the knowledge of contractual responsibility.

What makes a forecaster better than others is his use of the 'private knowledge' that has not found its way into the published literature (Hayes-Roth *et al.*, 1983). This private knowledge consists to a large extent on 'rules of thumb' that the forecaster has acquired over time. These 'rules of thumb' (or heuristics) enable the human expert to make educated guesses when necessary, recognise possible approaches to deal with problems and to deal effectively with uncertain or incomplete data (Hayes-Roth *et al.*, 1983; Brandon *et al.*, 1988). As a result of the uncertainty and lack of information that is present at the time the forecast is required, the above skills need to be heavily utilised by the individual (Brandon *et al.*, 1988).

The third generation of price forecasting models (Raftery, 1987) admit to the existence of uncertainty and incomplete knowledge (Bowen and Erwin, 1991), but most research work conducted on these models has resulted in 'black box' techniques. These techniques are characterised by the fact that any information put into the model (the black box) comes out at the other end without any intervention or enhancement by the consultant (Ferry and Brandon, 1991; Amkreutz, 1976)

The ability of the human expert is bounded when it comes to the handling of large amounts of data, as the human brain can only cope with a limited amount of information. By utilizing the experience and knowledge of experts, a more reliable and consistent solution in the form of an expert system can be developed to replicate some of the decision making process. The purpose of this chapter is to give a brief overview of the expert system environment along with their ability to handle the uncertainty that is present in the preparation of price forecasts in building projects.

6.2 EXPERT SYSTEMS

Before any further discussion follows, it is necessary to define what is meant by an expert system. Although many authors have given definitions that vary considerably, the writer adopts the definition given by Luconi *et al.* (1986), in which they classify an expert system as 'computer programs that use specialised symbolic reasoning to solve difficult problems well'. According to Luconi *et al.* (1986), one of the most important differences between expert systems and traditional computer applications is in their use of heuristic reasoning.

Two attributes of an expert system listed by Lansdown (1982) is their ability to give advice in probabilistic, rather than absolute terms and, secondly, their capability of explaining and justifying their reasoning. These attributes will assist in mastering the inflexibility of current models, and aid worthier price predictions of the future buildings (Smith, 1989). This is especially helpful where incomplete data and uncertainty is present (Brandon *et al.*, 1988). Nzioki (1987) lists some desirable attributes (which are perhaps better suited than other decision making tools) for price prediction in the construction industry, as being;

1. They have the ability to expand their knowledge base as additional information and/or experience is gained.
2. Expert systems are not rigid in nature and are able to handle any type of factual or heuristic knowledge.
3. They can include non-quantitive parameters in their reasoning.
4. They can cope with uncertain, unreliable or even missing information.
5. They can reflect, to a very large degree, special decision patterns of individual users.

Bowen and Edwards (1985), mention three additional attributes. These are;

1. The expert system provides a 'permanent copy' of the experts knowledge.
2. The vast available memory space can facilitate the contribution of more than one expert.
3. The expert system 'provides a clear basis for recording the best knowledge available for handling specific problems'.

An expert system can comprise of one or more of the following components, although no existing system contains all the components shown below (Hayes-Roth *et al.*, 1983).

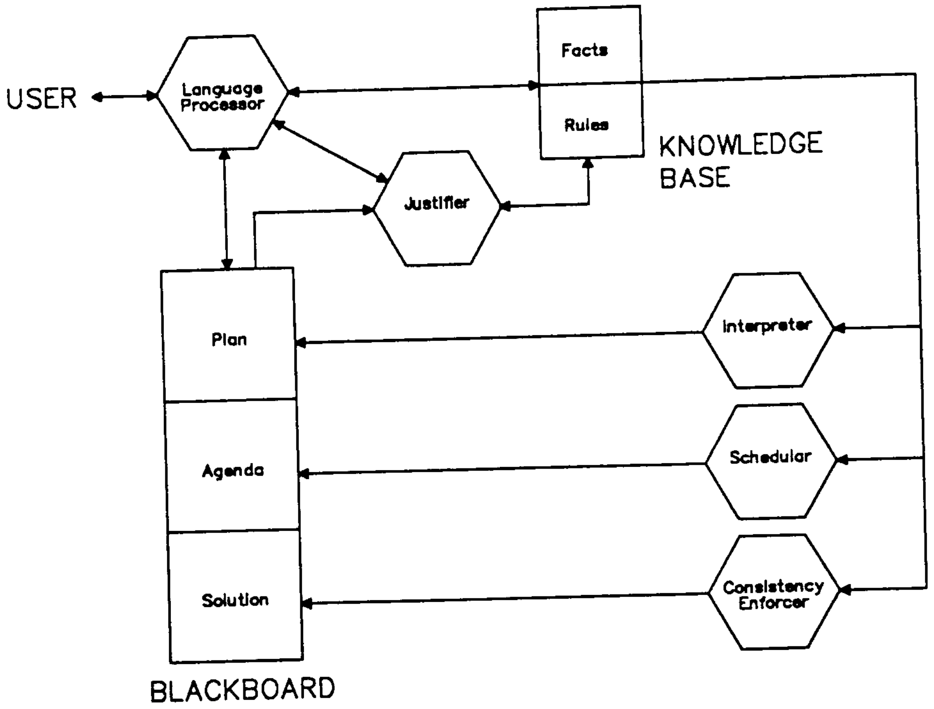

Fig. 6.1 Anatomy of an ideal expert system

As explained by Hayes-Roth *et al.* (1983), the language processor is used for problem orientated communications between the user and the expert system; the 'blackboard' for recording immediate results; the knowledge base is used to store the facts as well as the heuristic planning and problem-solving rules; the interpreter is used to apply the above mentioned rules; the enforcer adjusts previous conclusions when new data (or knowledge) alter the expert systems bases of support; and the justifier rationalises and explains the system's behavior.

As the knowledge base, inference engine, compiler and user interface are components that are incorporated in most systems (Brandon *et al.*, 1988), they will be dealt with a more detail.

a) Knowledge base

The human expertise captured in a specific domain is incorporated into an expert system in the form of knowledge. This knowledge may comprise of heuristics (rules of thumb) or an inference net that is stored as a model on the computer to form the knowledge base of the system (Brandon *et al.*, 1988). The knowledge base should also include the 'weighting' that the expert gives to those facts in order to represent the uncertainty he feels exists in those facts, as well as a mechanism which relates the 'rules' to the 'goals' (Smith, 1989).

The simplest form is shown by the

IF (rule) THEN (goal)

construct indicating that a certain outcome will occur if a certain rule is satisfied. It is sometimes extended to

IF (condition with probability x) THEN (goal with probability y)

indicating that some uncertainty exists.

b) Inference engine

The inference mechanism forms the link between the 'problem' and the information that is stored in the knowledge base (Smith, 1989). Most systems represent their reasoning in the form of 'forward chaining', 'backward chaining' or both (Brandon, 1987; Smith, 1989). Dealing with each of these in turn:

1. In forward chaining, once the answer to a question is given, the system scans all rules contained in the knowledge base until a suitable match is found. This process is repeated until the goal state is achieved or no usable rules are found (Brandon *et al.*, 1988). In other words, by steadily building upon the established information, the system is able to move forward through the information base until a conclusion can be reached (Smith, 1989).

2. In forward chaining, the system moves forward through a problem, possibly asking questions that are not relevant to the given situation. Backward chaining reduces the number of questions posed by tracing a path from the 'goal' back through the links of the inference net until a match is found with the information in the working memory. Any question that is not linked, even indirectly, to the goal is automatically considered irrelevant and not asked.

c) Compiler/checker

A compiler converts problem data and knowledge into a suitable form for manipulation by the inference engine (Brandon *et al.*, 1988).

d) User interface

The user interface is a communication tool between the developer and eventual user of the system, enabling the user to be guided through the program by following a number of steps which are designed to seek information about the problem area (Gray, 1987; Smith 1989; Brandon *et al.*, 1988).

6.2.1 ADVANTAGES OF EXPERT SYSTEMS

The expert system is able to cope with missing, uncertain, or even contradictory information in a natural way (Brandon *et al.*, 1988).

An expert system has the ability to explain its behavior through an explanation facility (Andriole, 1985; Adeli, 1988; Brandon *et al.*, 1988), which, according to (Brandon, 1987), gains the confidence of the user.

An expert system uses a systematic approach to finding the answer to a problem. It is therefore not biased by making cursory or irrational decisions (Andriole, 1985; Adeli, 1988).

Once the knowledge base has been constructed, it can be gradually and incrementally developed over an extended period of time (Andriole, 1985; Adeli, 1988).

An expert system can check the consistency of its knowledge entities or rules (Andriole, 1985; Adeli, 1986), and is therefore considered more reliable than the human expert (Brandon *et al.*, 1988).

Expert systems give their advice conversationally in the manner of the consultant (Lansdown, 1982).

6.2.2 LIMITATIONS OF EXPERT SYSTEMS

The interpretation of data by the system is sometimes difficult because it may be uncertain or incomplete (Hayes-Roth *et al.*, 1983).

Many features of human reasoning are not yet fully understood. For example, the way in which uncertainty and imprecision is handled and the way in which conflicts are resolved (Quinlan, 1983; Lansdown, 1983). It should be noted that these articles were published in 1983, and since then, much research has been conducted into the problem of uncertainty in expert systems.

A serious problem exists in capturing rare expertise, as experts in a knowledge domain may fear that, by giving up their knowledge, they may weaken their position within their organisation. The expert may also have other duties that prevent their spending an adequate amount of time with the knowledge engineer (Andriole, 1985; Adeli, 1988).

They lack common sense and intuition, and are unable to learn (Andriole, 1985; Adeli, 1988).

6.3 INCORPORATING UNCERTAINTY IN EXPERT SYSTEMS

Although different mathematical measures are available to describe uncertainties in a quantifiable form (Ross, 1988), it should be noted that **not all expert systems possess the ability to cope with uncertainty**. However, they can generally handle knowledge which is less structured than that required for conventional computing techniques (Brandon *et al.*, 1988). One of the important considerations to bear in mind when constructing an expert system, is that it should still be able to make decisions with incomplete information as well as solve the problem without knowing all the facts, as well as cope in the face of uncertainty (Ross, 1988).

The way in which an expert system incorporates uncertainty, is best explained by Ross (1988). In rule-based expert systems,

> "uncertainties of the antecedents (the IF part of the rule) are combined to give the combined antecedent uncertainty. This uncertainty is propagated along a rule and combined with the rule uncertainty to give the uncertainty in the consequent (the THEN portion of the rule), and the various consequent uncertainties are combined" (Ross, 1988, p.175).

The logic of this combination process is followed in both backward or forward chaining (Wong, 1986).

A strategy for assessing the uncertainty in the three parts of an inference engine (among antecedents, along a rule, among consequents), is to use the 'combination' process (also called the *approximate reasoning module*), which contains (Ross, 1988);

a) uncertainties associated with factual knowledge and

b) uncertainties associated with the inference rules.

> "The purpose of the inexact reasoning module is to combine different kinds of uncertainty including ignorance, into a global uncertainty measure associated with the final assessment" (Ross, 1988, p.176).

It is on the above assessment that the user will base any decision he has to make.

6.3.1 REVIEW OF UNCERTAINTY TECHNIQUES UTILISED IN EXPERT SYSTEMS

In order that the hypothesis, presented in Chapter One, be proved true, it is necessary to ascertain whether the uncertainty techniques presented in this thesis can be incorporated into an expert system. This will be done by reviewing some of the expert systems that make use of uncertainty techniques. Examples of such systems include:

1. **MYCIN** - A medical diagnosis expert system uses certainty factors and bayesian theory in dealing with uncertainty (Buchanan and Shortliffe, 1984; Sheridan, 1989).
2. **PROSPECTOR** - An expert system used in the exploration of minerals, utilises Baye's rules, probabilities and "odds likelihood" functions (certainty factors) to handle uncertainty (Ng *et al.*, 1988; Schafer, 1987; Martin-Clouaire and Prade, 1985).
3. **FAULT** - An expert system used to assess financial ratio analyses uses the theory of fuzzy sets (Whalen and Schott, 1985).
4. **SPERIL-I** - An expert system used to assess the damage caused to existing buildings by earthquakes uses decision analysis and probability theory (Ogawa and Yao, 1985).
5. **SPERIL-II** - A follow on from SPERIL-I, makes use of the techniques of SPERIL-I as well as fuzzy set theory and certainty factors (Ogawa and Yao, 1985).
6. **INFERNO** - Utilises bayesian theory and certainty factors (Pang *et al.*, 1987; Sheridan, 1989).
7. **RUBRIC** - An expert system used for information retrieval uses fuzzy set theory and decision analysis (Tong and Shapiro, 1985).
8. **GLADYS** - A medical system used for the diagnosis of Dyspepsia makes use of probabilities, certainty factors and bayesian theory (Spiegelhalter, 1987).

6.4 THE EXPERT SYSTEM PRICE FORECASTING MODEL

It has already been shown that expert systems are a suitable environment in which the process of price forecasting can be incorporated. As stated at the outset of this chapter, it is not the intention to present a working version of a price forecasting expert system, but rather propose a manner around which one can be developed.

It has been shown that certain of the uncertainty techniques mentioned in Chapter Four can be applied to price forecasting models, with all the techniques having the attributes of being incorporated into an expert system. It is therefore proposed that an environment be created which will, at any point along the design stage, 'choose' the most appropriate forecasting model based on the amount of information available at that time. It has been shown that the availability of information is the most significant variable affecting the provision of uncertainty by practitioners. The expert system would then, by means of a number of prompts from the system, apply all the information that is known at the stage of design. Then by following the logic of the price forecasting model chosen, it will produce the forecast along with a measure of the uncertainty associated therewith.

The uncertainty techniques would be built into the rules followed by each forecasting model and would be applied when any uncertain variable is indicated by the system user or, automatically if a process takes place that has, for some reason, an element of uncertainty associated with it.

In order for the above proposition to be made, the writer is under the opinion that a new classification of price models needs to be made with reference to uncertainty. Newton (1989, p.13) states the following with regards to the classification of forecasting models;

> "There are various cost estimating techniques being used and developed at present. Unfortunately, with no clear classification system it is often difficult to gauge where such developments may lead, or how any preferred technique compares with others."

It is proposed that the expert system to be developed will use this classification as the basis for the treatment of the uncertainty associated with price forecasting.

6.4.1 PROPOSED CLASSIFICATION

In a shift from the traditional 'two-dimensional' classification of price models (Raftery, 1984, 1987; Skitemore and Patchell, 1990), a third dimension is introduced (Newton, 1989). The proposed classification to be utilised by the expert system is broken down into three parts for the purpose of explanation. These three parts include a classification of price forecasting models, a classification of the uncertainty within each price model and, a classification of the technique used to treat uncertainty. Although presented separately, all three parts would be used simultaneously by the proposed expert system.

a) Classification of price forecasting models

The basic taxonomy is split into the three dimensions illustrated in Figure 6.2. These three dimensions include the price forecasting model, time and, the degree of uncertainty.

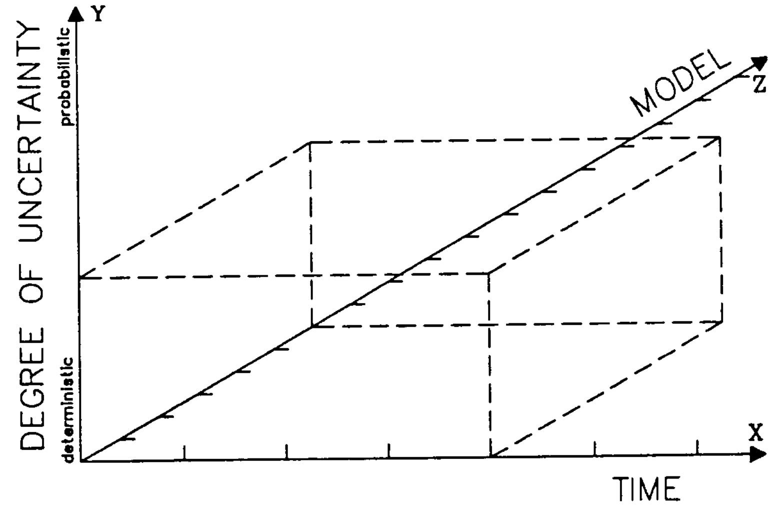

Fig. 6.2 Classification of price forecasting models

The price forecasting models have been placed on the Z-axis and would include all models used to provide a construction price forecast. The models are arranged on the Z-axis according to the amount of information needed for their 'successful' usage. The time, placed on the X-axis, represents the design stage of the construction process, with the origin denoting the start of the inception and brief stage of design. The degree of uncertainty, placed on the Y-axis, is used to denote the extent of the uncertainty within the price forecasting process, with the origin representing a deterministic model (*ie.* a price model that has not taken uncertainty into account). The problem space (Howard, 1968) included in Figure 6.2, represents the models used in this thesis.

b) Classification of the uncertainty within the price model

It is important to note that this classification is applied to each individual forecasting model and not to price models in general. The three dimensions used for this classification are time, effect and cause. The three dimensions are illustrated in Figure 6.3.

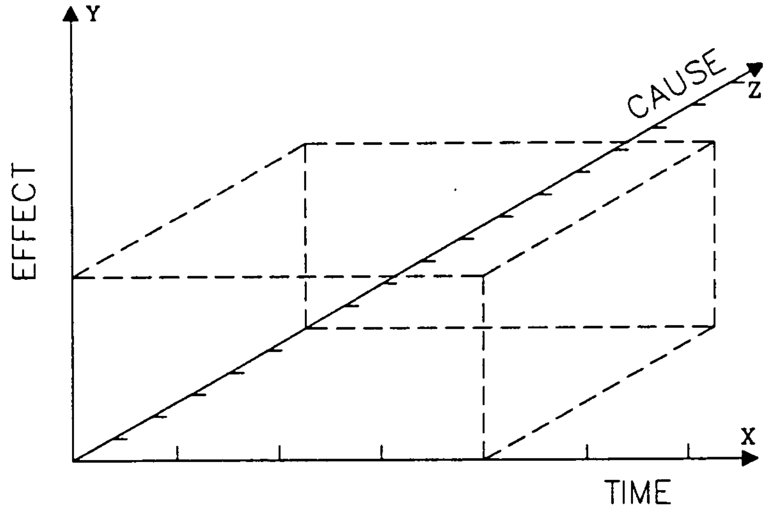

Fig. 6.3 Classification of uncertainty within price model

The X-axis of time represents the design stages in which the price model is used. The Z-axis is used as a basis of indicating the causes of the uncertainty associated with the price model, for example, the uncertainties of data, communication and information. The Y-axis indicates the effects that the uncertainty would have on the price model, for example, lower accuracy.

c) Classification of uncertainty techniques

It is important to note that this classification refers to the individual causes of uncertainty discussed above. The three dimensions used include time, problem and technique. The three dimensions are illustrated in Figure 6.4.

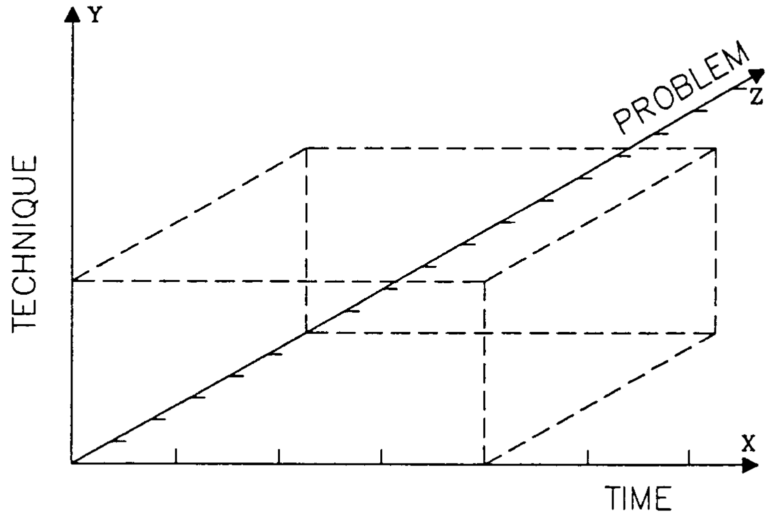

Fig 6.4 Classification of techniques used to treat uncertainty

The X-axis, denoting the time, represents the stage of design of the price model. The Z-axis is an analysis of the problems that led to the cause of the uncertainty in the price model. The Y-axis represents the techniques that can be used to treat uncertainty.

6.4.2 EMPLOYMENT OF THE 3-DIMENSIONAL CLASSIFICATION INTO AN EXPERT SYSTEM

As mentioned above, it is proposed that the three classifications be combined in order to be of use to the expert system. The combination of the three classifications is illustrated in Figure 6.5.

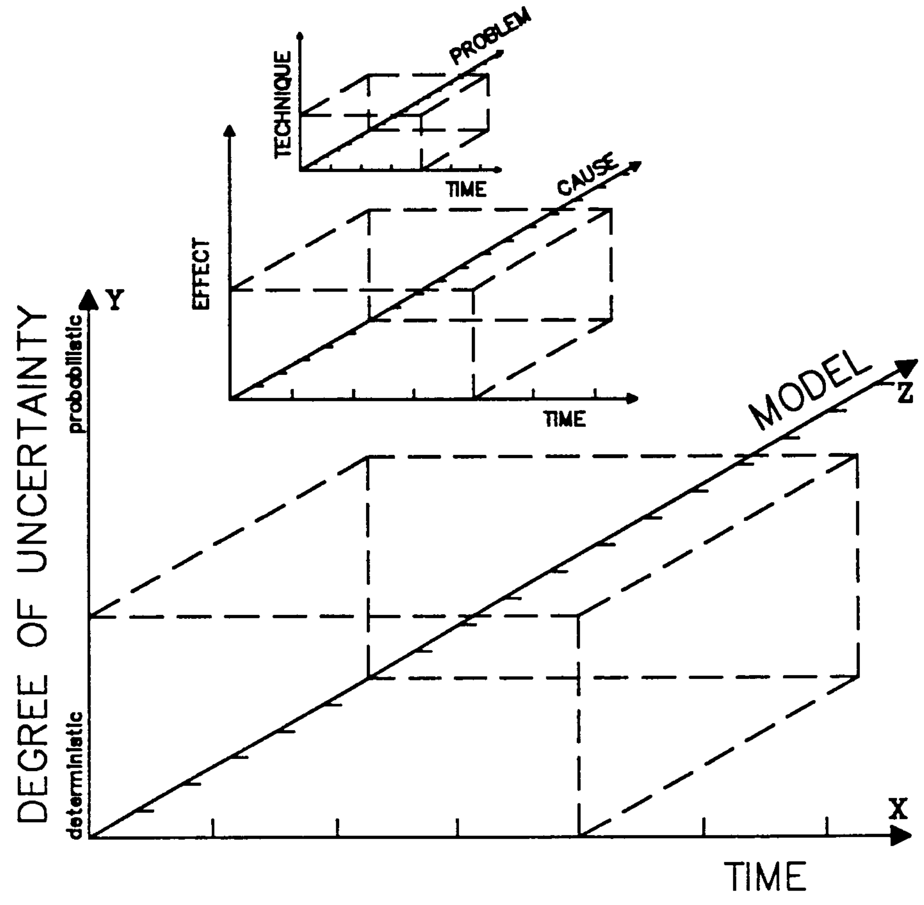

Fig. 6.5 Employment of the 3-dimensional classification

The three classifications, due to the time and uncertainty axis being common, can be placed in different positions within each other for greatest benefit. It is proposed that with the aid of prompts from the user of the expert system, the system will be able to abstract all the necessary information needed to produce a price forecast.

By means of evaluations, similar to those presented in Chapter Three and Chapter Four, it will be possible for the expert system to choose a price model that will best suit the available information. By means of evaluations of a similar nature, the expert system will also be able to apply one or more uncertainty techniques to the chosen price model in order to deal with any uncertainty that may be present at the time of the forecast.

The aforementioned modelling environment has not been discussed comprehensively. It is important to note is that the proposed system is conceptual in nature and is yet to be tested in practice. However, the underling principles hold promise in their ability to cope with the problems associated with the uncertainty in price models.

CHAPTER 7

CONCLUSIONS

7.1 INTRODUCTION

This study has dealt with the nature and treatment of uncertainty in construction price forecasting. The objective of this report has been to establish that quantity surveyors do not make adequate allowances for the treatment of uncertainty in traditional price forecasting models and, to show that an expert system modelling environment could be used to make adequate provision for this uncertainty. Based on the information and findings contained in this report, the following conclusions may be drawn.

7.2 NATURE OF UNCERTAINTY IN PRICE FORECASTING

The price forecasting process has a high level of uncertainty associated with it as a result of;

a) The inadequate transfer of information between the various members of the design team at the different stages of the design process.

b) The lack or incompleteness of the design information provided to the quantity surveyor by the architect.

c) The sources of data used by the quantity surveyor in producing the price forecast.

d) The variability in the data used by quantity surveyors in pricing the forecast.

e) The choice of an appropriate price model at the different stages of the design process.

7.3 THE UNCERTAINTY IN PRICE FORECASTING MODELS

The traditional price forecasting models used by quantity surveyors do not make adequate allowances for the uncertainty associated with the building procurement process and have a very high potential for uncertainty inducement as a result of;

a) The amount of detailed information needed by the price model to produce the forecast.

b) A heavy reliance being placed on the quantity surveyors past forecasting experience.

c) The format of the price models, which is reliant on the use of data that is variable in nature.

7.4 TECHNIQUES USED TO COPE WITH UNCERTAINTY

It has been established that certain statistical techniques do have the ability to cope with the uncertainty associated with the price forecasting process, and are suitable for incorporation into price forecasting models.

It has been established that the uncertainty techniques of probability theory, bayesian theory, fuzzy logic, decision tables, certainty factors and simulation can be incorporated into the price models used by practitioners.

7.5 UNCERTAINTY IN THE QUANTITY SURVEYING PROFESSION

Practitioners, although acknowledging the presence of uncertainty in the forecasting process, do not take adequate measures for the treatment thereof. It has been concluded that the amount of information, the cost of the project, the size of the project and, the time available, are factors that influence practitioners in their treatment of uncertainty.

7.6 TREATMENT OF UNCERTAINTY IN PRICE FORECASTING MODELS

Of the eleven price modelling methods mentioned, it has been shown that an expert system environment has the best characteristics for coping and treating the uncertainty associated with the forecasting process. It has been proved that an expert system environment has the ability to cater for the uncertainty associated with the price forecasting process, as well as having the attribute of providing the user with the reasoning behind the logic that the expert system has followed.

CONCLUSION

The hypothesis of this report was to establish that an expert system environment has the ability to incorporate, evaluate and communicate the uncertainty present in the price forecasting process. An expert system model for the incorporation of uncertainty has been presented and although conceptual in nature, it has the ability to handle the uncertainty associated with construction price forecasting. From the finding of this report, it is therefore concluded that the above hypothesis can be proved true.

CHAPTER 8

RECOMMENDATIONS

RECOMMENDATIONS

Based on the findings and conclusions of this report, the following recommendations can be made.

Practitioners should, in producing their price forecasts, take the uncertainty associated with the forecasting process into account in order to provide architects and clients with more meaningful and accurate indications of the final price of construction projects. In order to achieve this, practitioners ought to use one or more of the uncertainty techniques mentioned in this study.

As the proposed price forecasting expert system is conceptual in nature, it is recommended that further research be carried out in the field of expert systems. It is felt that the expert system environment offers the practitioners with the most adequate and appropriate method of treating the uncertainty in construction price forecasting.

Finally, it is recommended that any research work conducted into this field be done with the aim of producing a construction price forecasting expert system which is centered around the principles of the proposed three dimensional classifications of uncertainty.

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APPENDICES

APPENDIX I

QUANTITY SURVEYORS

SECTION ONE : DEMOGRAPHIC DATA

QUESTION 1.1 PLEASE INDICATE THE CURRENT FULL-TIME STAFF LEVELS IN YOUR OFFICE (LOCAL BRANCH).

	less than 3	between 3 and 5	between 5 and 10	between 10 and 20	more than 20	
Partners	84%	14%	2%	0%	0%	(92)
Associates	86%	11%	3%	0%	0%	(29)
Quantity Surveyors	72%	18%	7%	3%	0%	(61)
Technicians	89%	5%	4%	0%	2%	(56)
Students	98%	2%	0%	0%	0%	(45)
Other	88%	8%	2%	2%	0%	(40)

QUESTION 1.2 PLEASE INDICATE TO WHICH QUANTITY SURVEYING CHAPTER YOUR OFFICE BELONGS.

Western Cape	22
Eastern Cape & Border	6
Southern Transvaal	20
Northern Transvaal	13
Natal	26
O.F.S & Northern Cape	12

UESTION 1.3 PLEASE INDICATE THE FIRM'S AVERAGE GROSS ANNUAL TURNOVER, IN RESPECT OF BUILDING VALUE, OVER THE LAST 3 YEARS.

Average gross annual turnover in respect of building value over the last three years	R 3 200 510.50

The figures in brackets indicate the number of respondents for each variable

ECTION TWO : PRACTICE OF PRICE FORECASTING

UESTION 2.1 WHEN PRODUCING A COST ESTIMATE OR PRICE FORECAST, WHICH OF THE FOLLOWING METHODS DO YOU USE ?

	always	fre-quently	occasion-ally	seldom	never	
Functional unit	1% ✓	4%	11%	32%	53%	(76)
Super	3% ✓	16%	43%	25%	13%	(88)
Cubic	0% ✓	0%	6%	8%	86%	(73)
Storey enclosure	4% ✓	12%	11%	16%	57%	(75)
Approximate quantities	15% ✓	57%	20%	7%	1%	(86)
Elemental	31% ✓	38%	20%	5%	5%	(93)
Bills of quantities	12% ✓	28%	25%	17%	18%	(76)
Regression models	0% ✓	1%	5%	7%	87%	(74)
Expert systems	1% ✓	1%	4%	10%	83%	(70)

UESTION 2.2 DOES YOUR OFFICE USE ANY OF THE FOLLOWING RESOURCE-BASED METHODS TO PRODUCE AN ESTIMATE ?

	always	fre-quently	occasion-ally	seldom	never	
Critical path methods	0%	4%	12%	12%	72%	(85)
Activity bills	2%	4%	10%	21%	63%	(91)

The figures in brackets indicate the number of respondents for each variable

QUESTION 2.3 PLEASE INDICATE WHICH, IF ANY, OF THE FOLLOWING ESTIMATING METHODS ARE NORMALLY USED BY YOUR OFFICE DURING THE VARIOUS STAGES OF A PROJECT.

	inception & brief	feas-ibility	sketch design	detail design	tender	
Functional unit	83%	17%	8%	8%	8%	(24)
Super	92%	33%	15%	0%	0%	(78)
Cubic	100%	0%	0%	0%	0%	(6)
Storey enclosure	45%	55%	40%	5%	0%	(20)
Approximate quantities	23%	68%	85%	68%	5%	(75)
Elemental	31%	71%	85%	65%	8%	(78)
Bills of quantities	1%	1%	1%	33%	94%	(89)
Regression models	40%	40%	0%	20%	0%	(5)
Expert systems	30%	60%	30%	30%	0%	(10)

QUESTION 2.4 TO WHAT EXTENT DO YOU FEEL THAT THE VARIOUS ESTIMATING METHODS LISTED BELOW ARE CAPABLE OF MODELLING THE BUILDING PROCESS ?

	degree of representation					
	very good	good	accept-able	poor	very poor	
Functional unit	1%	3%	23%	52%	22%	(74)
Super	1%	6%	44%	40%	9%	(90)
Cubic	0%	0%	19%	46%	35%	(80)
Storey enclosure	5%	12%	38%	26%	19%	(80)
Approximate quantities	57%	38%	5%	0%	0%	(92)
Elemental	48%	41%	11%	0%	0%	(93)
Bills of quantities	93%	7%	0%	0%	0%	(95)
Regression models	6%	21%	41%	25%	8%	(53)
Expert systems	10%	32%	42%	12%	4%	(50)

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* The figures in brackets indicate the number of respondents for each variable

UESTION 2.5 PLEASE INDICATE THE ACCURACY OF METHODS USED IN THE PROVISION OF COST ADVICE (E.G. WITHIN 5%).

	expected percentage accuracy						
	0-5	6-10	11-15	16-20	21-25	above 25	
Functional unit	0%	17%	31%	24%	7%	21%	(29)
Super	0%	34%	34%	20%	3%	9%	(76)
Cubic	0%	21%	37%	16%	0%	26%	(19)
Storey enclosure	11%	40%	34%	3%	0%	12%	(35)
Approximate quantities	55%	36%	5%	4%	0%	0%	(83)
Elemental	49%	43%	5%	3%	0%	0%	(83)
Bills of quantities	92%	8%	0%	0%	0%	0%	(85)
Regression models	0%	40%	20%	27%	0%	13%	(15)
Expert systems	13%	31%	19%	25%	6%	6%	(16)

QUESTION 2.6 WHAT ARE THE EXPECTED ACCURACY LEVELS OF THE FORECAST AT THE VARIOUS STAGES OF THE PROJECT LISTED BELOW, RELATIVE TO THE ACCEPTED TENDER (E.G. WITHIN 5%) ?

	best	average	worst
Inception & brief	8% (53)	14% (60)	22% (52)
Feasibility	5% (53)	10% (59)	16% (50)
Sketch design	5% (55)	9% (57)	13% (50)
Detail design	3% (56)	6% (53)	11% (48)
Tender	3% (55)	5% (53)	9% (48)

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* The figures in brackets indicate the number of respondents for each variable

QUESTION 2.7 ON WHICH OF THE FACTORS LISTED BELOW, IF ANY, DOES THE ACCURACY OF THE FORECAST DEPEND ?

	always	fre-quently	occasion-ally	seldom	never	
Expertise	66%	29%	4%	1%	0%	(96
Good data base	38%	46%	14%	2%	0%	(95
Amount of information available	68%	30%	2%	0%	0%	(97
Suitability of forecast method at the different stages of the project	33%	36%	27%	4%	0%	(94
Chance	1%	5%	35%	25%	34%	(85
Method used	42%	41%	13%	4%	0%	(91

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* The figures in brackets indicate the number of respondents for each variable

SECTION THREE : USE OF DATA

QUESTION 3.1 WHAT FORMS OF COST DATA ARE KEPT BY YOUR FIRM ?

	yes	no	
Cost analysis	87%	13%	(87
Updated bills	89%	11%	(92
Price books (eg. Merkels)	64%	36%	(76
Price lists (eg. lists from suppliers)	86%	14%	(83

QUESTION 3.2 PLEASE RANK IN ORDER OF PREFERENCE, THE DATA THAT YOU PREFER TO USE IN COST ESTIMATING.

	first choice	second choice	third choice	fourth choice	fifth choice	sixth choice
Bill of quantities	49	21	6	0	0	0
Cost analysis	19	18	15	3	1	0
New rates	5	3	4	0	1	0
Experience	1	0	2	3	0	1
Price books	4	6	15	15	3	0
Price lists	7	14	12	9	1	0
Indices	0	5	5	0	0	0
Specialist quotes	0	3	3	2	2	0
	(85)	(70)	(62)	(32)	(8)	(1)

QUESTION 3.3 WHAT SOURCES OF DATA DO YOU USE IN COMPILING COST ESTIMATES ?

	always	frequently	occasionally	seldom	never	
In-house data	68%	30%	2%	0%	0%	(96
Published price books	4%	23%	28%	21%	24%	(86)
Specialist quotes	21%	61%	12%	5%	1%	(95

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* The figures in brackets indicate the number of respondents for each variable

JESTION 3.4 WHAT SOURCES OF DATA DO YOU NORMALLY USE DURING THE VARIOUS STAGES OF THE PROJECT LISTED BELOW ?

	inception & brief	feas- ibility	sketch design	detail design	tender	
In-house	93%	84%	86%	82%	77%	(95)
Published price books	27%	49%	56%	51%	44%	(39)
Specialist quotes	23%	50%	71%	80%	76%	(80)

JESTION 3.5 WHAT TYPE OF DATA DO YOU NORMALLY USE WITH YOUR ESTIMATING METHOD ?

	in-house data	published price books	specialist quote	other	
Functional unit	87%	13%	20%	0%	(30)
Super	97%	5%	11%	1%	(75)
Cubic	88%	0%	13%	0%	(8)
Storey enclosure	86%	0%	21%	5%	(29)
Approximate quantities	100%	28%	52%	0%	(86)
Elemental	99%	24%	51%	3%	(84)
Bills of quantities	94%	26%	60%	3%	(90)
Regression models	75%	0%	13%	3%	(8)
Expert system	50%	0%	50%	3%	(8)

he figures in brackets indicate the number of respondents for each variable

QUESTION 3.6 PLEASE REFER TO THE ESTIMATING METHODS MENTIONED IN QUESTION 2.3. WHAT METHOD DO YOU APPLY TO DETERMINE THE RATES USED TO COMPILE THE ESTIMATES AT THE VARIOUS STAGES ?

	inception & brief	feas-ibility	sketch design	detail design	tender	
Rates from previous, similar projects used are suitably updated for inflation, site conditions, market conditions, etc.	78%	74%	71%	69%	55%	(87)
Price books (eg. Merkels)	21%	38%	62%	69%	55%	(29
"Gut-feel" rates based on previous projects and experience	75%	55%	42%	29%	23%	(65)
Rates are calculated for each new project	7%	34%	55%	64%	61%	(44)
A library of rates kept for each of previous projects is put into a form which can be used for future projects	45%	60%	63%	50%	60%	(40)

* The figures in brackets indicate the number of respondents for each variable

SECTION FOUR : PRESENCE OF UNCERTAINTY IN PRICE FORECASTING PROCESS

QUESTION 4.1 **HOW DO YOU RATE THE UNCERTAINTY IN THE COMMUNICATION OF COST-RELATED ISSUES BETWEEN THE DIFFERENT PARTIES IN THE DESIGN TEAM (E.G. NO EXPLANATION OF CLIENT'S BRIEF BY THE ARCHITECT) ?**

	very high	high	accept-able	little	none	
Inception & brief	34%	55%	9%	1%	1%	(91)
Feasibility	10%	50%	38%	1%	1%	(91)
Sketch design	7%	25%	63%	5%	0%	(91)
Detail design	5%	7%	55%	33%	0%	(91)
Tender	6%	4%	31%	50%	9%	(90)

QUESTION 4.2 **HOW DO YOU RATE THE PRESENCE OF UNCERTAINTY IN THE DESIGN INFORMATION PROVIDED BY THE ARCHITECT AT THE VARIOUS STAGES OF THE PROJECT LISTED BELOW ?**

	very high	high	accept-able	little	none	
Inception & brief	60%	24%	13%	2%	1%	(94)
Feasibility	18%	54%	26%	1%	1%	(93
Sketch design	6%	34%	58%	2%	0%	(92
Detail design	2%	8%	50%	40%	0%	(92
Tender	4%	2%	31%	51%	12%	(92

QUESTION 4.3 **HOW DO YOU RATE THE PRESENCE OF UNCERTAINTY IN THE COST DATA USED TO PRODUCE FORECASTS AND ESTIMATES AT THE VARIOUS PROJECT STAGES LISTED BELOW ?**

	very high	high	accept-able	little	none	
Inception & brief	39%	27%	25%	6%	3%	(95
Feasibility	8%	38%	43%	8%	3%	(95)
Sketch design	2%	15%	62%	19%	2%	(94
Detail design	2%	2%	37%	55%	4%	(94
Tender	3%	2%	16%	51%	28%	(94

* The figures in brackets indicate the number of respondents for each variable

QUESTION 4.4 HOW DO YOU RATE THE DISTORTION OF DATA AS THEY ARE "TRANSFORMED" FROM THE SITE DATA, TO THE BILLS OF QUANTITIES, TO AN ELEMENTAL ANALYSIS.

	very high	high	acceptable	little	none	
Cost analyses	8%	11%	63%	17%	1%	(79
Bills of quantities	4%	11%	36%	44%	5%	(81
Price books (eg. Merkels)	17%	42%	30%	7%	4%	(71
Price lists (eg. lists from suppliers)	5%	22%	55%	13%	5%	(77

* The figures in brackets indicate the number of respondents for each variable

SECTION FIVE : TREATMENT OF UNCERTAINTY

QUESTION 5.1 **THIS QUESTION COVERS HOW YOU TREAT UNCERTAINTY IN COST ADVICE. DO ANY OF THE FACTORS LISTED BELOW INFLUENCE WHETHER OR NOT YOU TAKE UNCERTAINTY INTO ACCOUNT IN COST ADVICE ?**

	always	frequently	occasionally	seldom	never	
Cost of project	22%	39%	16%	14%	9%	(86
Lack of expertise	8%	19%	29%	21%	23%	(83
Size of project	18%	46%	18%	9%	9%	(88
Client type (eg. public sector client)	18%	28%	30%	14%	10%	(87
Lack financial feasibility	11%	29%	29%	16%	15%	(73
Client sophistication	11%	37%	25%	12%	15%	(85
Time available	15%	31%	23%	16%	15%	(80

QUESTION 5.2 **WHAT IS YOUR ASSESSMENT OF THE POTENTIAL OF THE ESTIMATING METHODS LISTED BELOW FOR HANDLING UNCERTAINTY ?**

	very good	good	acceptable	poor	very poor	don't know	
Functional unit	4%	0%	17%	33%	23%	23%	(84
Super	2%	6%	31%	46%	14%	1%	(94
Cubic	0%	4%	8%	34%	32%	22%	(85
Storey enclosure	2%	14%	31%	26%	12%	15%	(86
Approximate quantities	29%	46%	24%	1%	0%	0%	(91
Elemental	26%	57%	13%	3%	0%	1%	(95
Bills of quantities	75%	20%	3%	1%	1%	0%	(94
Regression models	4%	5%	15%	18%	4%	54%	(78
Expert systems	4%	8%	22%	7%	4%	55%	(78

* The figures in brackets indicate the number of respondents for each variable

QUESTION 5.3 **DOES YOUR FIRM USE ANY OF THE FOLLOWING TECHNIQUES IN THE TREATMENT OF THE UNCERTAINTY ASSOCIATED WITH COST ESTIMATES ?**

	always	frequently	occasionally	seldom	never	
Probabilities	5%	25%	26%	10%	34%	(92
Bayesian theory	0%	0%	0%	4%	96%	(75
Possibility theory	1%	8%	20%	14%	57%	(81
Fuzzy logic	1%	6%	11%	8%	74%	(81
Maximum/minimum ranges	3%	17%	33%	15%	32%	(85
Decision tables	1%	7%	0%	9%	83%	(78
Payoff tables	0%	4%	5%	4%	87%	(77
Certainty factors	5%	12%	9%	5%	69%	(80
Simulation (eg. Monte Carlo simulation)	1%	4%	7%	9%	79%	(76
Risk analysis	2%	12%	20%	16%	50%	(82
Other					100%	(4

QUESTION 5.4 **AT WHAT STAGES OF THE PROJECT WOULD THE TECHNIQUES LISTED BELOW BE IMPLEMENTED ?**

	inception & brief	feasibility	sketch design	detail design	tender	
Probabilities	63%	51%	22%	5%	5%	(59
Bayesian theory	64%	67%	0%	0%	0%	(3
Possibility theory	22%	29%	11%	3%	0%	(30
Fuzzy logic	21%	8%	5%	0%	0%	(19
Maximum/minimum ranges	24%	38%	18%	12%	6%	(76
Decision tables	23%	54%	23%	8%	0%	(13
Payoff tables	15%	54%	31%	15%	8%	(13
Certainty factors	20%	32%	44%	28%	4%	(25
Simulation (eg. Monte Carlo simulation)	29%	57%	14%	7%	14%	(14
Risk analysis	35%	57%	32%	19%	11%	(37

* The figures in brackets indicate the number of respondents for each variable

SECTION SIX : COMMUNICATION OF UNCERTAINTY

QUESTION 6.1 **CLIENTS AND ARCHITECTS ASK FOR AN ASSESSMENT OF THE UNCERTAINTY ASSOCIATED WITH COST ADVICE ?**

	yes	no	n/a	
Client	47%	49%	4%	(96)
Architect	38%	56%	6%	(94)

QUESTION 6.2 **HOW DO YOU COMMUNICATE INFORMATION THAT CONTAINS UNCERTAINTY, TO THE CLIENT AND ARCHITECT (E.G. GIVE A RANGE OF POSSIBLE VALUES).**

* The figures in brackets indicate the number of respondents for each variable

APPENDIX II

ARCHITECTS

QUESTION 1 THE NATURE AND TREATMENT OF UNCERTAINTY.

	yes	no	n/a	
In the provision of cost advice, is the presence of uncertainty acknowledged by the quantity surveyor ?	82%	13%	5%	(92
IF YES, is the nature of the uncertainty communicated to you ?	87%	7%	6%	(78

QUESTION 2 IF UNCERTAINTY IS ACKNOWLEDGED IN THE PROVISION OF COST ADVICE, IS ONE OR MORE OF THE FOLLOWING METHODS USED ?

	always	frequently	occasionally	seldom	never	
Probabilities	23%	56%	18%	1%	2%	(61
Bayesian theory	0%	3%	0%	30%	67%	(33
Possibility theory	2%	21%	23%	19%	35%	(43
Fuzzy logic	0%	17%	7%	32%	44%	(41
Decision tables	0%	14%	24%	16%	46%	(37
Simulation	10%	7%	30%	23%	30%	(40

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* The figures in brackets indicate the number of respondents for each variable

APENDIX III

CLIENTS

QUESTION 1 THE NATURE AND TREATMENT OF UNCERTAINTY :

	yes	no	n/a	
In the provision of cost advice, is the presence of uncertainty of cost-related issues acknowledged by the quantity surveyor ?	82%	13%	5%	(117

If yes, are one or more of the following methods used to quantify the presence of uncertainty ?

	always	fre-quently	occasion-ally	seldom	never	
Probabilities	12%	34%	16%	20%	18%	(74)
Bayesian theory	0%	4%	6%	6%	84%	(52)
Possibility theory	8%	5%	21%	7%	59%	(61)
Fuzzy logic	1%	29%	33%	8%	29%	(66)
Decision tables	66%	23%	5%	3%	3%	(61)
Simulation	0%	18%	15%	13%	54%	(60)

* The figures in brackets indicate the number of respondents for each variable