UNCERTAINTY IN BUILDING PRICE FORECASTING: PRICE DATA CONSIDERATIONS

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Abstract

The purpose of this paper is to consider aspects of the problem of uncertainty associated with building price forecasting. Emphasis is given to the uncertainty inherent in building price data, and the implications this has for the compilation of building price forecasts. More specifically, the price data generation process is examined, dealing with, *inter alia*, the structure and nature of price data, the inherent variability of price data, and the design/data/model interface. Finally, the results of a national questionnaire survey into the practice of the treatment of uncertainty in building price forecasting are described.

Keywords: Uncertainty; treatment; price data; price forecasting; cost estimating; communication; building.

1.0 Introduction

Much of the decision-making in the building procurement process takes place in an environment within which the objectives, constraints and consequences of possible actions are not known precisely (after Bellman and Zadeh, 1970). According to Bradshaw (1987), the decision-making process should have the ability to handle both the uncertainty that users have about their inputs, and that which experts have about their particular knowledge domain. Traditional approaches to price forecasting are generally deterministic in nature, with little representation of the uncertainty that is inherent in the knowledge domain. Clearly, for price forecasting techniques to be useful in solving `real-life' problems, the existence, identification and treatment of uncertainty must be accepted (Erwin *et al*., 1991).

Uncertainty may be defined as a state of knowledge about the variable *inputs* to an analysis (Marshall, 1988). Newton (1992) raises the issue of the distinction between *risk* and *uncertainty*. One school of thought (e.g., American Association of Cost Engineers, 1983; Black, 1984) holds that the former term is applicable to inputs that are measurable and to which may be assigned a probability of occurrence, and that the latter term applies to events to which a probability of occurrence cannot be assigned. Other writers dispute the necessity for this differentiation, using the terms interchangeably. For the purpose of this paper, and whilst acknowledging the conceptual difference between the two, the term `uncertainty' is adopted.

Price forecasting has been shown to be prone to uncertainty (Ashworth and Skitmore, 1982; Ogunlana and Thorpe, 1987; Ogunlana, 1989). Compliance with Jones and Twiss' (1978) *dictum* requires that a correctly formulated forecast should contain statements which are explicitly: (a) *quantitative*; (b) *qualitative*; (c) *related to time*; and (d) *stochastic* in acknowledging the uncertainty of the future event. This *dictum* applies no less to the provision of building price advice.

Evidence exists in the literature of the need for explicit treatment of uncertainty in price forecasting. For example, issues such as `probabilistic estimating' techniques (Spooner, 1974; Green, 1975; Morel, 1982; Diekmann *et al*., 1982; Diekmann, 1983); randomness in construction (Fine, 1976); measures of uncertainty (Blockley *et al*., 1983); and uncertainty assessment (Stacey, 1980; Beeston, 1982, 1986; Newton, 1992) have been addressed. Price models providing for the explicit treatment of uncertainty have been termed stochastic-simulation models (Bowen and Edwards, 1985) and third generation models (Raftery, 1987). In the empirical study performed by Newton (1991), it was shown that the *majority of the price models examined made no provision for uncertainty*.

This paper explores the stochastic qualification requirement of price forecasts. More specifically, the problem of uncertainty in price forecasting is examined with particular emphasis on the price data component, the practice of the treatment of uncertainty in the provision of building price advice is described, and the communication of uncertainty to the recipients of price advice is probed.

2.0 Theoretical aspects of the nature and treatment of uncertainty

Uncertainty can occur in an infinite number of forms (Fox, 1986) but, to date, no techniques exist that are able to handle all forms of uncertainty (Mamdani and Efstathiou, 1985; Marshall, 1988). Techniques for the treatment of uncertainty cannot transform the problem by the elimination of uncertainty. Rather, they provide a means of handling the issue of uncertainty more systematically (Cohen, 1985; Toakley, 1989). It is, therefore, necessary to match the various techniques for dealing with uncertainty against the context within which that uncertainty occurs, in an endeavour to establish those characteristics best suited to particular situations. Many authors (e.g., Buchanan, 1982; Tong, 1982; Klir, 1987; Allwood, 1989; Ng and Abramson, 1990; and Erwin *et al*., 1991) have compiled classifications of various types of uncertainty, but these classifications are not definitive. Such a classification philosophy has already been proposed within the property valuation context (Scott *et al*., 1988), namely, imperfect knowledge, intrinsic randomness, inherent indeterminacy, and categorical uncertainty. Imperfect knowledge refers to a situation (for example) whereby the quantity surveyor does not have, or is not certain of, the information needed for the analysis. This is probably the most common form of uncertainty inherent in the building price forecasting process. In the provision of design-to-price advice at the design concept stage the uncertainty in this instance would relate not only to the *quantum* of work to be provided, but also to the price for that work.

Intrinsic randomness relates to a situation which is not yet known but, given its occurrence, will possess a given probability affecting its outcome. Resulting from the assumed premise would be the conclusion that the information was subject to uncertainty. For example, if a proposed commercial office project is to be (say) higher than three storeys, then the probability of that building having a reinforced concrete framed structure is 80%.

Inherent indeterminacy arises where more than one reason can be assigned to any one particular outcome i.e., a `many-to-one' functional mapping occurs. For example (Scott *et al*., 1988), the dampness present on the inside face of a wall may be caused by condensation, a burst pipe chased into the wall, or an ineffective damp-proof course in the brickwork. The probabilities assigned to each of these causative factors are a measure of confidence in the truth of the facts, and sum to unity because it is certain that the dampness is caused by one of the factors.
Categorical uncertainty, which can be said to be widely applicable to the building procurement process, describes a decision process in which the goals or constraints are `fuzzy' in nature. `Fuzzy' set theory is a technique conceptualised by Bellman and Zadeh (1970), and refined by Zadeh (1979) and Pang *et al*. (1986), for dealing with situations where goals and constraints constitute classes of alternatives whose boundaries are not sharply defined and where the single-valued answers under Boolean logic do not appear applicable. For example, the assertion that a particular building has luxurious finishes is imprecise by virtue of the fuzziness of the term `luxurious finishes'.

Erwin *et al*. (1991) consider that a more fundamental approach to the classification of types of uncertainty is required. They argue that such a classification should take cognisance of the logic-flow of the *situation* in which the uncertainty arises, and not merely classify discrete examples of that uncertainty. The traditional view of uncertainty is anecdotal i.e., uncertainty of outcome, whereas in reality uncertainty is often abductive i.e., uncertainty of explanation (cause) as opposed to uncertainty of outcome (effect). An appropriate form of classification would thus be *uncertainty of outcome* and *uncertainty of explanation*.

Uncertainty of outcome would arise as a result of uncertain input variables to the decision-making process i.e., there is uncertainty as to how a variable input factor will affect the final outcome in the forward-chaining of logic. For example, if internal finishes of a certain quality are used, inexact consequences will result in respect of the price of the finishes, the time required to perform that work, and the consequential effect on the rentals achievable for that building. This classification would encompass the imperfect knowledge, intrinsic randomness, and categorical uncertainty categories provided by Scott *et al*. (1988).

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 price 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 price exceeding the budget. This classification would encompass the inherent indeterminacy and categorical uncertainty decomposition advocated by Scott *et al*. (1988).

The emphasis in this paper lies on uncertainty of outcome, or imperfect knowledge.

Various techniques, drawn from classical decision theory, are available for the treatment of uncertainty in building price forecasting. These include, *inter alia*: probability theory; Bayesian theory; possibility theory; fuzzy logic; range forecasting; decision tables; payoff tables; certainty factors; simulation (e.g., Monte Carlo simulation); and risk analysis. It is not within the scope of this paper to provide a detailed account of these analytical techniques. A comprehensive treatment is provided by Levin and Kirkpatrick (1978). Suffice it here to establish the extent to which quantity surveyors avail themselves of such techniques in the treatment of uncertainty associated with the provision of building price forecasts.

2.0 The nature of uncertainty in building price forecasting: price data considerations

2.1 Introduction

A means of examining the `interference' or `uncertainty inducement' associated with price forecasting was to examine the potential for uncertainty inducement associated with each of the constituent parts of the basic form of traditional price models.

The generic form of traditional price models may be represented as:

$$P = [(p_1 + p_2 + ... + p_n) + G].I \qquad \textbf{(Eq. 1)}$$

$$= [\ \sum_{i=1}^{n} (q_i r_i) + G\ ].I_i \qquad (i = 1, ..., n) \qquad \textbf{(Eq. 2)}$$

$$= [\ \sum_{i=1}^{n} (q_i r_i).I_i + \sum_{j=1}^{k} (q_j r_j).I_j\ ] \qquad (i = 1, ..., n; j = 1, ..., k) \qquad \textbf{(Eq. 3)}$$

where:

P	= total price of the work
p	= the individual product price of each item or work package
q_i	= measure[1] (quantity) associated with the i^{th} item or work package
r_i	= price per unit[2] measure of the i^{th} item or work package
q_j	= the measure associated with the j^{th} preliminaries item or work package
r_j	= price per unit measure of the j^{th} preliminaries item or work package

[1] Adjusted in respect of quantity - assumed to be linear in that economies/diseconomies of scale are ignored.

[2] Adjusted in respect of quality - represents an attempt to account for specification differences between the building chosen for comparison and the current project.

n = the number of items or work packages
G = the price of the preliminaries
I = a general price index for time adjustment
I_i = a price index for the time adjustment of the i^{th} item or work package
I_j = a price index for the time adjustment of the j^{th} preliminaries item or work package

In the application of the measures `q', these adjustments are assumed to be linear by virtue of substituting the new measures for the originals without adjustment for economies/diseconomies of scale. The prices per unit measure, `r', are adjusted for quality and time. The former adjustment refers to specification differences between the building chosen for comparison and the current project, whereas the time adjustment refers to the adjustment of historic price data by means of an appropriate price index. Different indices may be used for different elements or components.

Thus, for example, in application of the superficial method, Eq. 3 reduces to:

$$P = [\ \mathrm{E}_{i=1}^{n}\ (q_i r_i)].I_i \qquad (i = 1, ..., n)$$

where `q' is the area of each respective building function and `r' is the quality and time adjusted rate per square metre of each functional gross building area. In the pricing of bills of quantities, Eq. 3 is applicable in its entirety. The differences that occur between traditional price forecasting models are usually related to the number and type of items and the derivation and degree of detail involved in determining their respective `q' and `r' values.

Conventional thinking holds that more reliable price forecasts can, *ceteris paribus*, be obtained by more reliable `q' values , more reliable `r' values, or more items. Here the accuracy of the `quantity' measure depends on the level of design information available (together with the assumptive ability of the quantity surveyor), whilst the accuracy of the `unit rate' measure is seen as a function of the nature and extent of the database of price information available to the quantity surveyor (together with the judgemental ability of the quantity surveyor). In essence, when the quantity surveyor exercises assumptive and judgemental ability in the compilation of a price forecast, a process of intrapersonal communication is initiated. Clearly, the more explicit and logical the intrapersonal communication process, the more likely it is that the resultant price messages will be meaningful.

A means considered appropriate for addressing the issue of uncertainty in price forecasting is to examine the potential for `uncertainty inducement' inherent in price models themselves. In this context, `uncertainty inducement' is the potential of price models to `generate' uncertainty. Most price models consist of units of work, *quanta* of the units of work, and prices attached to the quantified units of work. It would seem reasonable, therefore, to assume that the potential for `uncertainty inducement' within the model itself is a function of the potential for `uncertainty inducement' associated with each of the constituent parts: namely, the nature and number of items or work packages; measures; and price rates per unit quantity of the work item. This assumption flows directly from the generic form of traditional price models represented by Eq. 3.

Insofar as `uncertainty inducement' within the three constituents is concerned, a number of issues are considered relevant, namely:

Item or work package	: the nature and extent of the items incorporated in the forecast.
Measure or quantity	: the source of the measure and its variability.
Price rate per unit measure of work	: the nature and derivation of the price rate, its weighting and currency.

Research in the United Kingdom over the last twenty years has focused on these three factors, the main emphasis being at the item level (e.g., Morrison, 1983; Stevens, 1983). It is beyond the scope of this paper to examine the potential for uncertainty inducement inherent in each of the three constituents described *supra*, suffice it to focus on the price data used by quantity surveyors in the compilation of price forecasts.

The remainder of this section is devoted to examining the price data constituent of the generic form of traditional price models.

2.2 Price data considerations

It is clear from the generic form of price models traditionally used by quantity surveyors that the nature and extent of input data, in the form of design information and price information affecting the number of items `n' and assessments of `q' and `r', is crucial.

The importance to the quantity surveyor of receiving the requisite quality and quantity of design information necessary to service the information needs of price models at the various stages of design is obvious, as is the relationship between design information, the client's brief and price forecasting. The emphasis in this section, without minimising the importance of meaningful design information, is on the implications of price data for uncertainty in building price forecasting. Commentary will be focused on the nature and importance of price data in the price modelling process, highlighting some of the issues and problems associated with such data. The process of applying judgement and decision-making in the choice and manipulation of price data clearly impacts on the quality of the eventual output information (price message).

The accounting view of data adopts a formal, traditionalist standpoint. Ijiri (1965) states that such an approach is characterised by `hardness', by which is meant that data are seen as unbiased representations of the reality they purport to measure. This view appears to have dominated quantity surveying practice to date. Under this doctrine, the emphasis has been on the use of data without thought to their statistical properties, degree of uncertainty, distortion and relevance to the design and building processes (Bowen and Edwards, 1985).

2.2.1 The source and usage of price data

It has been established (Bowen, 1993) that quantity surveyors have an inherent preference for in-house data such as price rates from bills of quantities and elemental and component price analyses derived from previous projects. The use of updated historic rates obtained from priced bills of quantities appears to be the most utilised form of price data throughout the design process, both in terms of magnitude and consistency. Published price data are seen by quantity surveyors as a secondary source. The popularity of `in-house' data stems from the fact that users are familiar with the projects from which the data were derived, and can thus transpose the data (with or without adjustment) with confidence to new projects. This familiarity affects the manner in which the price data are discriminated and grouped. Published price data do not facilitate such a level of understanding.

Flanagan (1980) found that a major shortcoming in the collection and analysis of data by quantity surveyors is the lack of a suitable system of identifying or classifying families of prices. It has been established that the homogeneity of the sample of buildings selected as the basis for future predictions has an important influence on price (Flanagan, 1980). However, the current popular method of price planning and control, whereby elements of a building are analysed according to their functional use, is of little assistance in the identification of price significance - the very basis of homogeneity. The lack of a classification system clearly has the potential to adversely affect quantity surveyors' ability to discriminate between different types of price data.

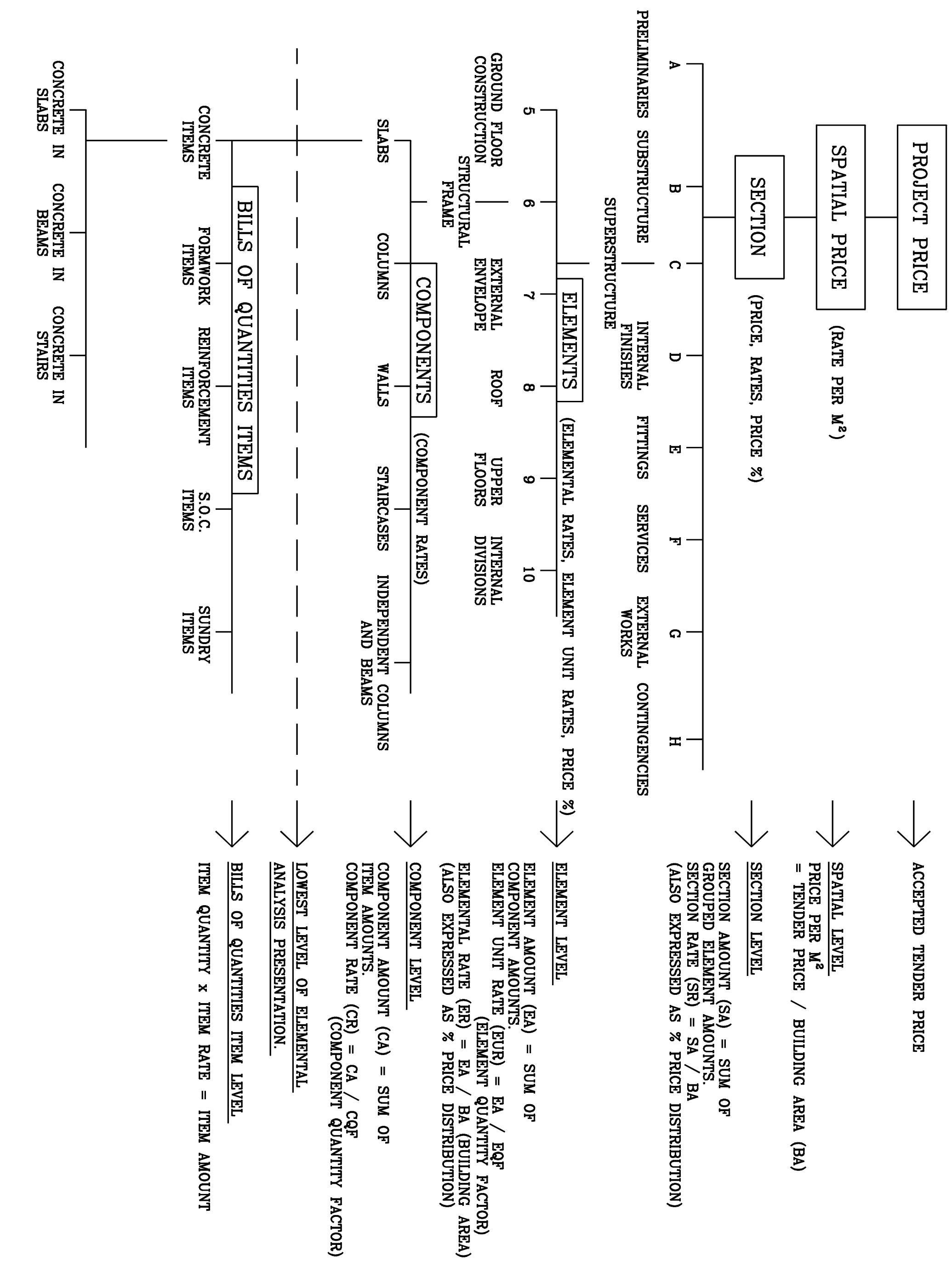
2.2.2 The structure of price data

The building industry has adopted a hierarchical structure for its price data, the nature of which is depicted in Figs. 1 and 2. It will be shown that this hierarchical structure is, in fact, an obstacle to the development of meaningful price models.

Researchers have been preoccupied with the lack of suitable price data of the quality needed to service the price forecasting methods used by quantity surveyors (Stevens, 1983). It is here that the nub of the problem lies. This data structure is not sensitive to the design/data/model interface (Raftery, 1984), nor is it commensurate with the production process of buildings, or the manner in which contractors price activities of building work. These anomalies will be addressed throughout this section. The emphasis here is on unit pricing, the pricing of the preliminaries being dealt with in Section 2.2.7.

2.2.3 Price data as a continuous generation process

There is a need to maintain a continuity of price data in an apparently changing, but actually continuous, process of development which marks most building projects (Miller, 1988). Building projects may be thought of in terms of a complex but continuous process of development towards a defined objective. This can be contrasted with the discontinuity of price data available for most projects, especially in the absence of a comprehensive database. Each stage will have different price data requirements, but discontinuity arises when the type of data generated in one stage of a project differs from, and is difficult to reconcile with, price data generated at another stage.



Consider conventional price planning and control practice in terms of the I.S.A.A. (1989) `Plan of Work'. A major price planning function associated with the inception stage consists of the provision of an assessment of the overall price of the building, and is usually derived using a technique such as the price per square metre of floor area or the price per functional unit. The appraisal and design concept stages involve the acceptance by the client of the strategic price forecast, as well as acceptance of related factors such as the anticipated size of the project, and amount of usable floor space.

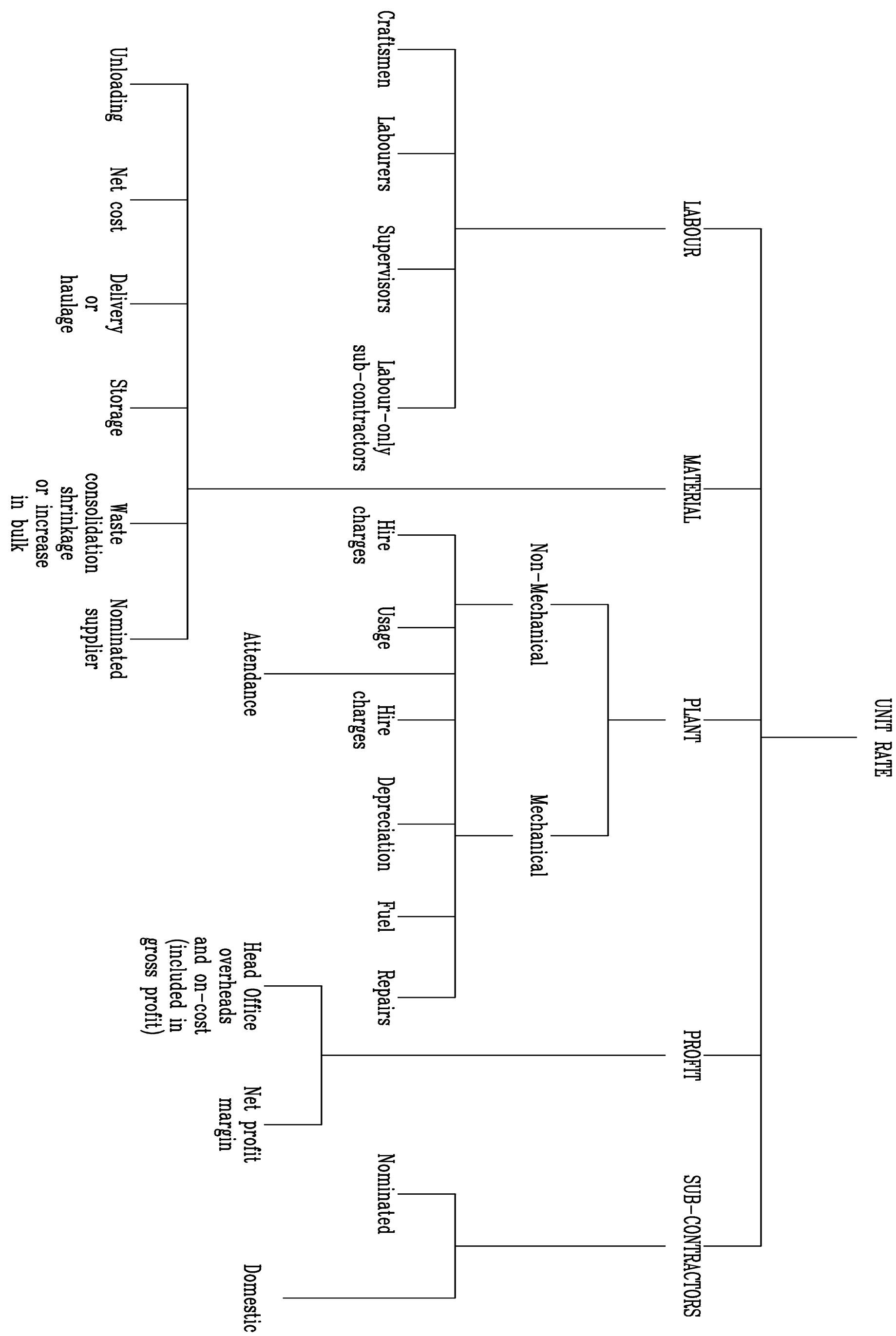


Fig. 1 The hierarchical structure of price data

Fig. 2 Components of a unit price rate (adapted from Ashworth, 1988)

The price planning functions associated with the design concept and design development stages consist of assisting in the development of the design, accompanied by the parallel development of an elemental price plan for the building. This price plan divides the building into functional price elements, using elemental price data *which are unrelated to those used in the previous stages*. Such price data are derived from the elemental analyses of previous, similar projects, and are applied to the functional elements of the proposed project ignoring the fact that they may not relate to the prices of construction of those particular elements. Furthermore, the functional interrelationships between elements, often used in isolation for price planning purposes, is ignored (Marston, 1985).

The documentation stage, from a price planning point of view, involves the price checking of the working drawings using the approximate quantities method of price forecasting. The components of building work which characterise this method of price forecasting are based on units of finished `work-in-place' measured in terms of the `Standard System' (A.S.A.Q.S., 1992), and *do not relate in any meaningful manner to the functional elements used in the elemental price forecasting method*.

The preparation of the bills of quantities involves the detailed measurement, in accordance with the `Standard System', of the finished `work-in-place' that constitutes the particular project. These measurements are grouped into `Trades' and, in fact, constitute a re-definition of the work in that these `Trades' *differ appreciably from the functional elements used for elemental price forecasting*. Furthermore, the groupings are at a lower level of abstraction to those inherent in the approximate quantities method of price forecasting.

The bills of quantities are usually priced as the final pre-tender forecast of the anticipated construction price of the building. The price data used in the pricing of the bills of quantities are derived from either the bills of quantities of current, similar projects, or calculated from first principles using the latest material price lists/quotations and the latest wage figures. It has been established that the former method is the more prevalent in practice (Bowen, 1993). Clearly, this form of price data bears *not the slightest relation to that used in the preparation of the elemental price plan, and hence is unrelated to the decision-making processes at previous stages*.

Upon receipt of the priced bills of quantities from the contractor, the quantity surveyor performs a `check' on the price rates contained therein. This checking function comprises examining the level of the rates, highlighting any abnormally high/low prices for sections of the work, and detecting any computational errors. The relevance of this to the generation of price data becomes evident if one considers the process of pricing the bills of quantities by the contractor. Contractors' estimators use little or no formal analysis in doing so (Miller, 1988) because they use the *process of production* as the basis for their pricing. *This differs from the items and categories presented in bills of quantities*. Thus, it is postulated that the item price breakdown of the total price submitted by the contractor is nothing more than a notional breakdown, a hypothetical construct (Higgin and Jessop, 1965). Indeed, an examination of the bills of quantities for tenders where the overall tender prices are very close reveals often widely differing rates for identical items, and even for the same trades (Beeston, 1975, Ashworth, 1983).

At the onset of the contract administration stage the main emphasis falls on price control. More specifically, the quantity surveyor advises the architect of the price implications of any design and/or specification changes to the contract, and is charged with submitting regular financial reports to the client. In addition, progress payment recommendations are computed at monthly intervals, these forming the basis for the interim payments to the contractor. However, the items in the bills of quantities (which form the basis of the payment computations) bear little or no relation to the production operations on site. The contractor is thus obliged to base project cashflow expectations on the basis of an artificial medium of computation. This renders the control of costs by the contractor all the more problematic as it is difficult to correlate costs incurred as a result of site operations with progress payment claims and payments made on the basis of a hypothetical construct. Given these difficulties in maintaining cost control, *how is accurate and reliable price data feedback possible?*

The latter part of the contract administration stage and the debriefing stage concerns the completion of the project and the feedback mechanisms. The major price control function here is the preparation and settlement of the final account. The final account includes, not only the measured *quanta* of work associated with approved variations but, in addition, monetary amounts in respect of adjustments to the preliminaries, contract price adjustment provisions (escalation), and sundry items such as dayworks. The format of the final account is essentially similar to that of the bills of quantities. Item price rates in the original bills of quantities are used as the basis for pricing the work embodied in variation orders. Given the format of the final account, *it is extremely difficult to facilitate the feedback of price data to any of the previous stages, especially to the preparation of a reconciled, `final' form of elemental analysis*.

Clearly, although price analyses may be prepared, in various forms, by quantity surveyors as the basis for the preparation of price forecasts for future projects, *discontinuity in the price data process* exists. Given this discontinuity, the ability of quantity surveyors to select and manipulate price data is seen as a direct function of their ability to assign intrapersonal meaning to those price rates. This is seen as a source of uncertainty in building price forecasts.

2.2.4 The nature of price data

The quality of the input price data has been established as a factor affecting the quality of price forecasts (Skitmore *et al*., 1990). However, any consideration of price data quality needs to address the issue of data transformations, the relevance of price data to the cost generation process, and the variability of price data.

2.2.4.1 Data transformations

Consider the process by which data are transformed from those generated on site to those utilised by quantity surveyors for price modelling. Figures 3 and 4 depict this process.

The elemental price data used by quantity surveyors are conventionally obtained from elemental analyses performed within quantity surveyors' own organisations, being derived from the priced bills of quantities of historic projects. The tender figures are the summation of the product of the unit rates and their associated items of measured work. Consider the unit rates themselves. Data, by their very nature, purport to be objective. However, subjectivity distorts the data in two important ways. Firstly, during the recording of the procedures on site and, secondly, during subsequent transformations of the data to produce `information' for various procedural requirements.

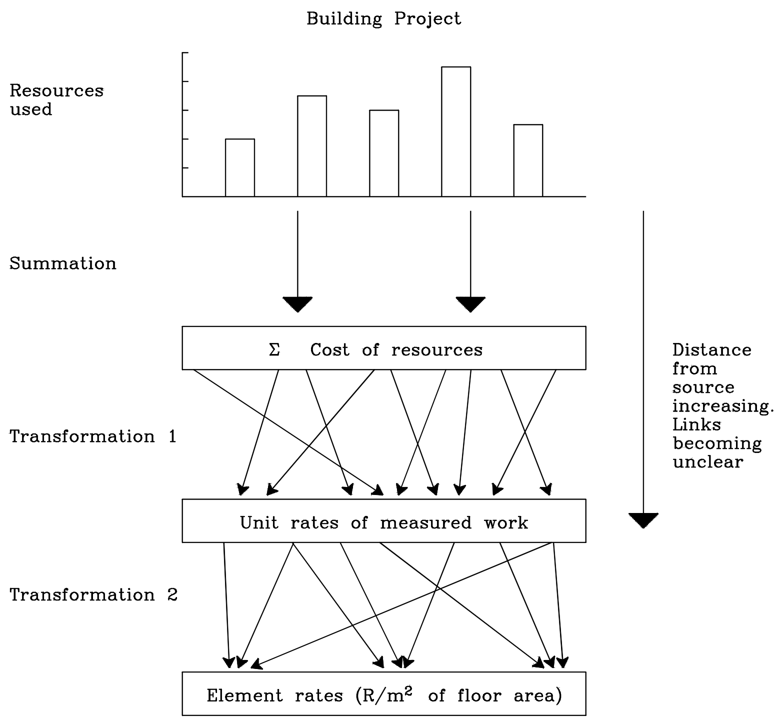


Fig. 3 The data transformation process (Raftery, 1987)

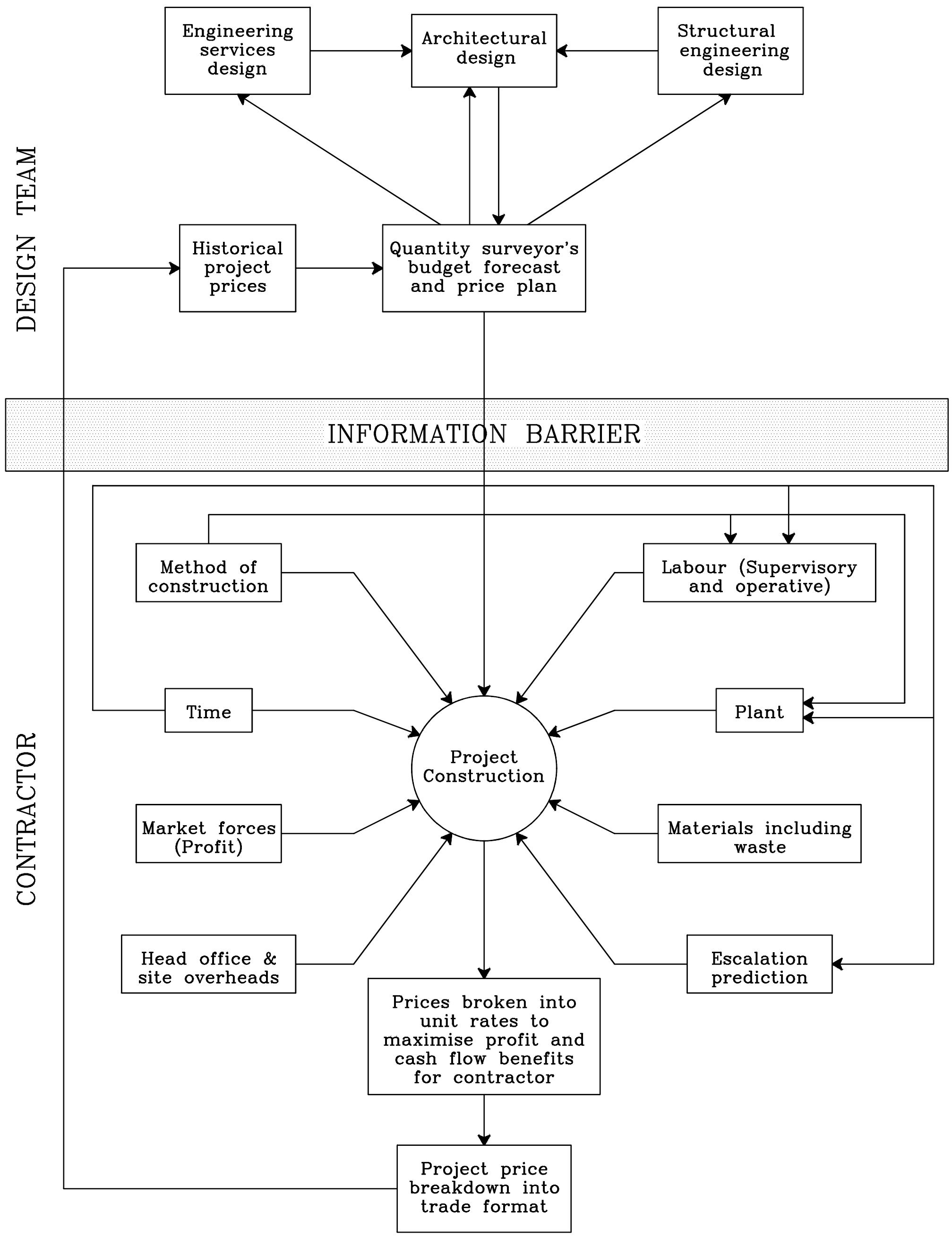


Fig. 4 The relationship between unit price rates and costs (Flanagan, 1980)

The first transformation occurs at the recording stage, where the time taken to perform various tasks of work is recorded on site by the contractor for cost control purposes. Doubts exist as to the reliability of this recording process, suffice it to state that this is a source of data distortion. At the tender stage, the sum of the resource costs for specific operations, work packages, network activities or subcontract work is spread over the unit rates to produce the priced bills of quantities. There may be `loading' or manipulation of rates to influence the timing of the contractor's monetary recovery from the building client. Numerous other factors affect the validity of the data; for example, the format of the on-site data recording being compatible with the manner in which the estimator prepares the estimate; variable productivity being a function of supervision, weather and delays; variable material usage, wastage and cost a function of worker skill and supervision; the variable nature of plant utilisation; and the increasing importance of labour-only sub-contracts. The factors affecting the composition of the unit rate include the method of distributing a proportion of the preliminaries costs over the measured items of work, anticipated variations and site conditions, contract conditions, size and complexity of contract, and the location of the project.

Once the cost of the resources is computed, an amount in respect of `mark-up' is added. The magnitude of the `mark-up' is influenced by certain strategic factors. Four possible combinations of fixed and variable cost estimates and `mark-up' exist (Skitmore, 1981), these being fixed estimate with fixed `mark-up', fixed estimate with variable `mark-up', variable estimate with fixed `mark-up' and variable estimate with variable `mark-up'. Newton (1983) asserts that the process of cost generation produces tender distributions which display variability very much in accordance with that described by the variable estimate and variable `mark-up' combination.

Clearly, *the concept of `unit' price rates for items of finished `work-in-place' is quite notional*, producing bills of quantities in which the tender price is based on variable and inherently inaccurate assumptions concerning labour output, material usage and plant efficiency.

The second transformation occurs when the unit rates from bills of quantities are subdivided and grouped by the quantity surveyor as a basis for producing elementally-based project price analyses in a *post-facto* manner in accordance with the `Guide' (A.S.A.Q.S., 1982). These elemental rates tend to be used at the earlier stages of the design phase when there is comparatively little detail. An alternative to the creation of elemental rates is the aggregation of bill rates to form the basis of the price data used in the approximate quantities method of price forecasting, a method favoured in the latter stages of design.

Clearly, *the rates utilised in the elemental and approximate quantities methods of approximate price forecasting have been the subject of distortion, and bear little relation to the production process*.

The price data emanating from the data generation process are thus uncertain in the estimating process (in terms of estimator assumptions regarding labour output, material usage and plant efficiency) and uncertain in the price analysis process (via the inherently subjective application of general `rules'). As Newton (1983) points out, **given that the `rules' governing how an operational cost is related to a bills of quantities item, and how the bill item is then related to a functional (elemental) price, are not manifest, the generation of price *cannot be deterministic***.

The difficulties associated with the treatment of price data by quantity surveyors is compounded by the fact that quantity surveyors are not party to the decision-making processes of contractors and that any assessment is entirely subjective. Given the uncertainty associated with price data, and in the absence of statistically qualified price data, the quantity surveyor has to rely entirely on judgement and experience - integral components of the intrapersonal communication process.

2.2.4.2 Data incompatibility with cost generation

The costs associated with contractors' operations are generated by the use of constituent resources used in the building process. It is clear from the foregoing arguments that *price data contained in price analyses and bills of quantities (and used in price modelling) are incompatible with the cost generation process*, raising questions as to their relevance and prominence in the process of price forecasting.

2.2.4.3 Variability in price data

The principle weakness associated with using any form of unit price rate approach in price forecasting is that it neither recognises, nor deals with, the fundamental problems caused by price variability (Flanagan and Norman, 1983). In an attempt to determine the quality of data and explicitly qualify its attributes, increasing use is being made of descriptive statistics.

Any particular price datum belongs to a family or population set of relevant price data. For example, the price/m^2 on elevation of a one brick wall (unit price rate), the price per linear length of strip footing (component price rate), and the price/m^2 on plan of the structural frame of a building (elemental price rate), all belong to separate population groups, each group displaying the collective characteristics of the individual statistics that comprise the group. Hence, the practice of selecting an `appropriate' rate for an item of work without consideration of the underlying characteristics of the population of rates is to assume that the chosen rate is totally representative of the item in question. Such an approach ignores the variability of price data and is deterministic in nature.

Many authors have addressed the issue of the variability found in trades and individual items of work (e.g., Beeston, 1975; Mathur, 1982; Ashworth, 1983; Flanagan and Norman, 1983; Morrison, 1984; Raftery, 1987; Hardcastle *et al*., 1988). All have demonstrated the possibility of extremely high variability at individual item level, even in instances where tender price variation is relatively low.

For example, Ashworth (1983) contends that, on average, tenders may vary by as little as 10%, but that individual trades may vary by 40-50%, and individual items by as much as 200%. Bennett *et al*. (1980) claim that individual price rates may vary by as much as 100%. It has been shown (Mendel, 1974; Beeston, 1975) that item prices tend to be distributed about their mean in a skewed manner, high prices tending to be further above the mean than low prices tend to be below it. Beeston (1975) suggests that the coefficient of variation for individual, similarly described items of work is much greater than for complete projects. More specifically, Beeston (1975) suggests that the coefficients of variation for identical buildings in the same location would be in the order of 8.5%, whereas the typical figures for trades could range from 45% (Excavator) to 13% (Glazier) - indicative perhaps of the differences in perceived uncertainty attached to those trades.

Flanagan (1980) asserts that the individual prices for measured items exhibit greater variability than prices at the trade level or for entire buildings, with measured items showing a variability of up to eight times that of tender totals. The degree of variability at all three levels is seen as a function of the homogeneity of the sample (Flanagan, 1980).

To illustrate the uncertainty associated with item price rates, rates for eight different items of measured work typically found in bills of quantities were obtained from the Bureau of Economic Research (B.E.R.). These rates were supplied to the B.E.R. in the first instance by ten quantity surveying firms in the Western Cape. To ensure a reasonable sample size, rates for two consecutive months (July and August 1990) were collected. The August 1990 rates were adjusted to July 1990 using the building price indices supplied by Medium-Term Forecasting Associates. The rates for the various items are given in Table 1, and various measures of dispersion presented in Table 2. No account is taken of contract size or contractor status.

Table 2 illustrates the variability found in practice in price rates for the eight items of work. In this example, the coefficient of variation was found to be as high as 50% for the identical item of measured work. These findings lend credence to the notion that price rates contained in bills of quantities are merely a *notional breakdown of the overall tender price and are tempered with so many tactical considerations as to render them largely unreliable for price modelling*. This is seen as cause for concern given the fact that priced bills of quantities are the major source of price data used by quantity surveyors.

Table 1 Variability of item price rates (July 1990 constant prices)

	Price rates for items of work (R)									
Item of work	July 1990 rates							Adjusted August 1990 rates		
	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 (general)	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 cement 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 Measures of dispersion of item price rates

	Measure of dispersion of item price rates				
Item of work	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 (general)	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 cement 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

Table 3 presents the suggested characteristics of the constituents of a unit price rate for building work. It would seem reasonable to conclude that distinguishing between a `right' and `wrong' price may become extremely difficult. In this instance, the term *objective* is used to denote assessments made with recourse to empirical, ascertainable data, whereas *subjective* assessments are made without adequate recourse to the actual data.

Table 3 Suggested characteristics of the constituents of a unit price rate for building work (Bowen and Edwards, 1985)

Price constituent	Variability	Assessment method
Material cost	low	objective
Material wastage	moderate	usually subjective
Labour cost	low	objective
Labour productivity	high	objective, but with significant subjective influence
Resource (plant) costs	low	objective
Resource utilisation	high	objective, but with significant subjective influence
Overhead recovery	high	objective, but with significant subjective influence
Profit expectation	high	generally subjective

The problem of item price variability is exacerbated by the sampling techniques employed by most quantity surveyors for price forecasting purposes. Using just one item price rate from a historic project is a tactic fraught with risk, yet one frequently resorted to by quantity surveyors (Property

Services Agency (P.S.A.), 1981). Furthermore, few price forecasts prepared by professional quantity surveyors give explicit consideration to the confidence limits attached to the range of prices within which the eventual outcome is expected to fall (Bowen and Edwards, 1985).

In this context, the findings of a national postal survey and the empirical study are of relevance (Bowen, 1993). With the possible exception of price rates from bills of quantities, the majority of quantity surveyors see price data as having undergone a transformation. Respondents consider the presence of uncertainty (variability) in the price data used for price forecasting to be unacceptably high until the design concept stage. However, in-house data, the data preferred by quantity surveyors, is seen as possessing less variability than other forms of data. **Notwithstanding the acknowledged presence of uncertainty in price data, quantity surveyors make little formal provision for the quantification and treatment of uncertainty in the provision of price forecasts**. Clearly, this shortcoming has implications for the compilation of building price forecasts. Misperceptions are likely to result.

2.2.5 The design/data/model interface

The issue of data discontinuity discussed above may be viewed as part of the overall problem of the design/data/model interface, the essence of which is reflected in Fig. 5.

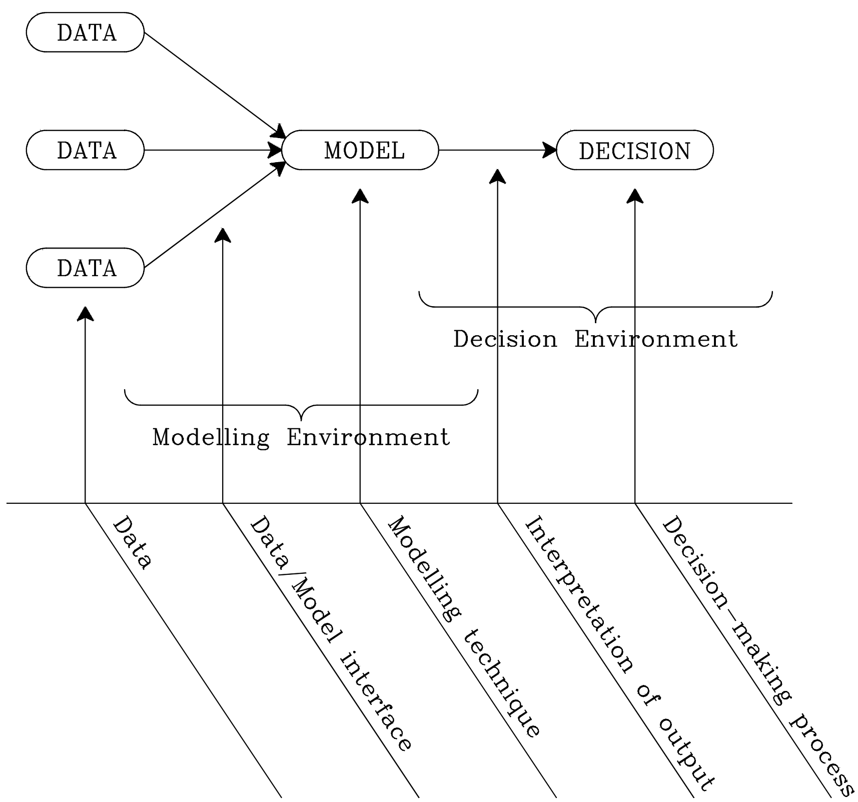


Fig. 5 The design/data/model interface (Raftery, 1984)

The problem is that for effective price forecasting in the servicing of the information needs of architects and clients, the correct flow of information must take place at the appropriate time; consist of the correct quantity; be of an appropriate quality; and be relevant to the decision-making process it is trying to facilitate.

2.2.5.1 The design/data interface

In consideration of the environment within which price models operate in the service of the design function, whether the traditional view of the design process as a sequential, linear activity (I.S.A.A., 1989) is favoured, or whether the model of design as a cyclic, iterative process is adopted, the important factor is that the design process commences with the client's brief and progresses through various stages of refinement, culminating in the development of the agreed design and, finally, the working drawings. Commensurate with this is the view that price modelling moves through parallel states of increasing accuracy (P.S.A., 1981). This may be seen as a progression from non-specific data to project-specific data which indicate, in broad terms, the general level of design at which the particular price model operates.
In consideration of the relationship between design and the data used for price modelling, the question of whether or not there exists an available set of price data at a level of detail commensurate with the level of detail of design, needs to be addressed. More specifically, *the level of detail of the price data and the level of abstraction of design at that stage need to be matched*. This necessitates the establishment of the price-related information requirements of clients and architects, and the level of design-related information available to the quantity surveyor. If the price data are at a coarser level of detail than those needed to satisfy the information requirements of design, then the more fundamental problem of improving the quality of the recorded data needs to be examined (Raftery, 1991).

2.2.5.2 The data/model interface

In consideration of the relationship between a price model and its price data, there are two main issues to be addressed. Firstly, is there an available set of price data which is at a level of detail suitable to that of the model? The level of detail which will facilitate maximum benefit to be derived from the model, requires definition. In other words, *the level of detail of the price data and the price forecasting model need to be matched*.

Secondly, if price data and price model are not well matched, it is necessary to establish whether the data are at a greater level of detail than the model, or *vice versa*. If the former is the case, refinement of the price modelling technique needs to occur to maximise the benefits to be derived from the existing data. Conversely, if the price data are at a coarser level of detail than the model, then either a more appropriate price model needs to be employed or the problem of improving the recorded data needs to be addressed (Raftery, 1991).

The area model is a method commonly used for the determination of a project budget limit before any drawings are available. Discounting the worth *per se* of this technique, this model is selected as it is seen as matching the coarse nature of the available price data and the level of the design information available - notwithstanding the acceptance on the part of quantity surveyors that this method does not adequately represent the construction process (Bowen, 1993).

It has been established (Bowen, 1993) that quantity surveyors have a clear preference for applying as detailed a method of price modelling as possible at the earliest opportunity, possibly without due consideration of the degree of matching between the design information available, the level of abstraction of the price model, and the price data servicing the model. Personal preferences are a key issue here - they are based on the familiarity of the quantity surveyor with the price forecasting technique, the perceived potential for accuracy inherent in the model, and belief as to the degree of matching of the design/data/model interface. Clearly, this intrapersonal communication process impacts on the eventual quality of the price message.

2.2.6 Updating of price data

The purpose of a price/cost index is to measure changes in prices or costs, from one point in time to another, in relation to a base date. Its relevance to price forecasting is represented by `I' in Eq. 3.

In price forecasting, quantity surveyors place extensive reliance on price and cost indices as the basis for adjusting price information. Examples of such manipulations include the adjustment of historic item price rates drawn from bills of quantities; historic price analyses and project price forecasts from the date of forecast to the anticipated tender date; as well as assessments of anticipated escalation during the currency of the contract for inclusion in the overall price forecast at contract completion. As previously noted, the B.E.R. Building Cost (sic) Index and the `Haylett Formula' factor-cost index, respectively, are used for these manipulations in South Africa.

Apart from the fact that these indices are weighted statistical averages, designed to represent average situations and having little relevance to individual projects, a major problem associated with these indices is the time lag in publication. The B.E.R. index (1975=100) is a monthly index, published quarterly, approximately three months in arrears, with the latest available indices specified as being provisional. For example, in the April 1991 publication of `*Building and Construction*' (B.E.R., 1991), the indices for the period January 1990 - February 1991 were denoted as being provisional. This problem is further compounded where indices are denoted as being based on a statistically invalid sample size. One index is compiled for the entire country, but averaged current item price rates for the twenty-two representative items are given on a quarterly basis. Project specific indices relating to different categories of buildings are available on a quarterly basis. No indication of the base date is provided - one assumes it is 1975=100. In addition, a quarterly labour cost index (1985=100) and a building material price index (1985=100) are included.

The lack of region-specific price indices is, to an extent, overcome by the publication by the B.E.R. of a (quarterly) confidential report to members of the Association of South African Quantity Surveyors, entitled `*Trends in Building Costs*'. This document, in addition to the information contained in the `*Building and Construction*' and `*P0151 - Haylett*' publications, contains the following data:

: Details of sample size.

: Quarterly B.E.R. building cost index (1962 - to date) (1975=100).
: Quarterly, regional B.E.R. building cost index (no base date).
: Monthly and year-on-year percentage changes in the building cost index (1975=100).

The `Haylett' indices, whilst compiled for a number of geographic regions, are published approximately three months in arrears. Their usefulness in price forecasting is further reduced in that individual, weighted indices are not produced for commercial and industrial buildings. The validity of the `Haylett' indices is brought into question by revisions to the component weightings and the frequent revision of individual indices. Both the B.E.R. publications discussed above provide details of the `Haylett' Work Group (WG) 24.1[3] (1975=100) index, but the information is six months in arrears.

The Central Statistical Service `P0153' Contract Price Index for Buildings, published on an *ad hoc* basis and between six and nine months in arrears, contains

: Details of sample size (by region and building type).
: Quarterly weighted average contract price index (1980=100).
: Quarterly, regional weighted average contract price index (1980=100).
: Quarterly weighted average contract price index by building type (1980=100).
: Averaged current item price rates for representative items on a regional basis.

The major problem associated with the use of these indices is one of time-lag in publication. This problem is, to some extent, obviated in that Medium-Term Forecasting Associates compile a monthly report of projected monthly B.E.R. (1970=100 and 1975=100), `Haylett' WG 24.1 (1975=100) and Central Statistical Services `P0153' (1980=100) indices for up to 5 years ahead. These projections, available commercially, are revised on a continuous basis.

Differences and changes in base dates render inter-index comparisons difficult. Much reliance is placed on *subjectivity* in the application of indices. For example, doubt exists as to which index is applicable in any specific circumstance, and the applicability of the `Haylett' WG 24.1 index is questionable as it relates to lump sum domestic buildings. **Notwithstanding the importance of indices such as these, very little is known or published about their quality and accuracy**.

2.2.7 Time sensitivity

In terms of traditional price models, the price of any measured item is given by `p = qr', where `q' is the quantum of work and `r' is the unit price rate. However, `r' may also be represented as:

$r = f(x,y,z)$ **(Eq. 4)**

---

[3]Work Group 24.1 relates to `lump sum domestic buildings'.

where:

x = price of materials
y = price of labour
z = price of plant

Further items may be included in this (additive) model to reflect other components such as the price of supervision. Clearly, the labour (y) and plant (z) components are time-dependent so that:

$$\begin{aligned} p &= qr \\ &= q(x + y + z) \\ &= qx + q(y,z) \end{aligned} \qquad \textbf{(Eq. 5)}$$

The significance of time as an influencing factor depends entirely on the magnitude of the term `(y,z)' relative to other terms in Eq. 5. This term is, in turn, affected by the manner in which labour and plant are combined, depending on the degree of substitution of plant for labour. In terms of the derivation of the unit price, with the labour component accounting for some 40%, **it is evident that the time aspect of the work has a strong influence upon the total price**.

Notwithstanding the strength of this relationship, quantity surveyors take little direct account of activity duration when determining item price rates, being primarily concerned with the relationship between price and the quantity of finished work. The problem is exacerbated by the fact that quantity surveyors do not usually calculate item rates from first principles, but rather draw the information from rates obtained from the bills of quantities of `comparable' projects. Even when considered within the context of homogeneous buildings, considerable variability exists because of factors such as project size, timing, location, repetition and complexity. Clearly, subjectivity plays a major role in the assessment and selection of `comparable' item price rates.

In South Africa, the time for completion of the contract is usually stated as given information to tenderers in the tender documents. This is generally determined from a knowledge of performance on contracts of a similar type and size. Such predictions of contract duration are inherently inaccurate because of the following factors (Flanagan, 1980):

: published information on duration/performance is inadequate at best,
: design information at early design stage, when duration prediction is needed, does not lend itself to reliable time prediction, and,
: measured items in bills of quantities are insensitive to the time aspects of construction, even though many of the items are demonstrably time-sensitive.

Bromilow (1969), Fine (1974), Bennett (1978), Flanagan (1980) and Atkin (1988), amongst others, have considered the implications of construction time for price. For instance, it has been found (Flanagan, 1980) that a low correlation exists between construction price and construction duration, *despite the fact that price is the factor most frequently used by quantity surveyors to predict contract* *duration*.

Most price forecasting methods traditionally used by quantity surveyors make only indirect reference to contract duration. The `*Guide to Elemental Cost Analysis*' (A.S.A.Q.S., 1982) requires only the overall contract period to be stated on the price analysis summary form whilst traditional (trade) bills of quantities, even though they may state the contract period, do not specifically consider the sequence of activities for a project, nor the time required for any particular activity in the building process.

Quantity surveyors appear to rely totally on intuitive assessments of time, a practice fraught with uncertainty given the low correlation between time and price. Consequently, even when item price rates are calculated from first principles, the time component is subjectively determined. Little published material exists in South Africa on building activity durations. Thus, the assumptive and judgemental skills applied by quantity surveyors in the intrapersonal communication process are without a firm basis. This must be seen as a source of uncertainty in price forecasting.

Given the importance of the effect of activity duration on item price, it is desirable that the time implications of construction be considered during the pre-tender phase when design decisions are taken, and that price forecasting techniques be capable of reflecting the relationship between contract duration and price.

The issue of the relationship between contract duration and the `*preliminaries*' is also of relevance. The `preliminaries' section of bills of quantities contains those items generally unrelated directly to individual items of work. Examples include site accommodation, general plant (e.g., a tower crane), scaffolding, temporary services, and insurances. Preliminaries items may be considered as falling within four main categories, namely: time-related (e.g., site accommodation); method-related (e.g., temporary works); quantity-related (e.g., temporary hoardings); and price-related (e.g., insurances). Clearly, certain preliminaries items fall into more than one category; for example, plant is time-related, method-related and quantity-related. The majority of items are time-related to some degree. The `*Preliminaries*' document published by the A.S.A.Q.S. (1991) for use with the Joint Building Contracts Committee (J.B.C.C.) `*Principal Building Agreement*' (J.B.C.C., 1991) makes provision for items contained in the preliminaries section to be priced by the contractor as either `fixed', `variable with value' or `variable with time', or a combination of these. This breakdown is then used as the basis for the payment and the adjustment of the preliminaries.

Consider the method adopted by most quantity surveyors in the pricing of preliminaries. The basic form in which preliminaries items are represented in bills of quantities is that of `$E(q_j r_j)$' (Eq. 3). Throughout the early design stages when approximate price forecasting techniques are used, and often when pricing bills of quantities as the final pre-tender price forecast, quantity surveyors usually adopt the procedure of adding on a percentage allowance to the priced builders' work. This percentage allowance is usually obtained from an analysis of priced bills of quantities of a `similar' nature, with an intuitive adjustment allowing for the differences between projects. This presupposes that there is knowledge of the composition of the preliminaries and the relevant items which should be adjusted because of the varying circumstances of the project. The pricing of the preliminaries must be seen as a potential source of considerable forecasting error given that this section can account for some 15-20% of the tender value. Contractors recognise the dangers inherent in this approach, preferring to adopt an individual assessment of each project to calculate the work content and cost of each preliminaries item (Bennett *et al*., 1980; C.I.O.B., 1983).

Research in the United Kingdom (Flanagan, 1980; Gray, 1981) showed that preliminaries, when expressed as a percentage of contract value, display wide variability. This variability is not significantly affected by the size of the project, its type of construction or complexity. *There is also no significant correlation between the preliminaries percentage and the value of the project*. The relationship between the preliminaries and the overall duration of the project reflects a higher correlation, which improves further in projects of a more complex nature. However, the standard data sources and methods of price forecasting used by quantity surveyors do not consider this relationship at all. The percentage addition approach, determined in relation to the value of the project, is highly subjective and unrelated to the process of construction. A dearth of published data exists regarding the percentage contribution made by preliminaries to tender price for various types of projects. This must be seen as a source of uncertainty in price forecasting.

Gray (1981) concluded that, as a detailed study and calculation of a construction programme is not a feature of quantity surveyors' normal price forecasting practice, quantity surveyors are unlikely to change the method of pricing preliminaries *without becoming more involved in, and aware of, the implications of the construction programme and its relationship with building design*.

2.2.8 Uncertainty in building price forecasting - a price data viewpoint

It has been established in this study that the price data emanating from the price data generation process are uncertain. This stems from the estimating process within the contractor's organisation, and from the price analysis process undertaken by the quantity surveyor. The uncertainty results from the subjective application of ill-defined `rules' governing data manipulation. Similar uncertainty applies to the choice and application of indices used to update price data and price forecasts, and the prediction of contract escalation.

This `interference' to the intrapersonal communication process can be traced to the assumptions, perceptions and judgements of the participants in the process. Much of the uncertainty lies in the decisions taken by the participants e.g., whether labour productivity is seen as being good or bad; whether the market is perceived as being competitive or not; whether a particular price model is deemed appropriate under certain circumstances; whether work activity should be categorised in one element or another; whether a particular price rate is considered appropriate; and the choice, manipulation and application of a particular index. Consequently, the nature of this `interference' ultimately equates to how judgements are made; namely, *human behaviour*. In essence, the assumptive and judgemental ability of the quantity surveyor employed in the intrapersonal communication process associated with the selection and manipulation of price data is of crucial importance.

It has been shown (Osgood *et al*., 1957) that *meaning*, a major determinant of human behaviour, possesses two characteristics, namely:

: It is contextual i.e., dependent on the situation.
: It resides in people i.e., it is variable and imprecise.

The nature of `uncertainty' in the process of price data generation can be equated with the nature of meaning; namely, that it too is contextual and variable, and subject to interpretation depending on the meaning assigned to it by the forecaster. *It can, therefore, be concluded that the process of selecting and manipulating price data and price/cost indices for price modelling purposes possesses an intrapersonal dimension, and will vary from person to person*. Clearly, the subjective manner in which price data are dealt with in price modelling has implications for the compilation of price forecasts.

3.0 The practice of the treatment of uncertainty in the provision of building price advice

An overview of the price data generation process associated with price forecasting has been presented. Clearly, the amount and quality of the information available to quantity surveyors for price forecasting purposes and the price forecasting method utilised, impacts on the quality of price forecasts. Thus, insofar as the *information* requirements of price forecasting is concerned, the accuracy of a price forecast is dependent, to a greater or lesser extent, on the

: degree of uncertainty associated with design information provided by the architect,
: uncertainty attached to the price data used for price forecasting, and,
: extent to which price data are distorted via the feedback process as they are transformed from data held by the contractor's estimator to those presented in the form of price rates in bills of quantities and elemental or component rates.

In an endeavour to establish the nature and extent of the treatment of uncertainty in practice, the opinions of clients, architects and quantity surveyors were sought by means of a national postal questionnaire. The remainder of this paper is devoted to a discussion of these findings.

3.1 Uncertainty in design information

It has been established (Bowen, 1993) that the majority of quantity surveyors (84%) consider the presence of uncertainty in the design information provided by the architect at the inception stage to be unacceptably high. Only at the design concept stage, and subsequently, do the majority of quantity surveyors (60%) consider the presence of uncertainty in design information to be at an acceptable level. Thus, *the design information upon which quantity surveyors base their price forecasts is subject to unacceptably high levels of uncertainty until the design development stage, with `acceptable' levels thereafter*.

3.2 Uncertainty in price data

Apart from the uncertainty attached to the design information provided by architects, uncertainty exists in the price information used by quantity surveyors in price forecasting. The opinions of quantity surveyors were sought regarding the presence of uncertainty in price data used at the various stages of the design process for price forecasting purposes. These results are shown in Table 4.

Table 4 Presence of uncertainty in price data

Design stage	Frequency of occurrence		
	Very High / High	Acceptable	Little / None
	(%)	(%)	(%)
Inception	65	25	10
Appraisal	45	43	12
Design concept	17	62	21
Design development	4	37	59
Documentation	5	16	79

Clearly, respondents perceive that the level of uncertainty attached to price data used for price forecasting diminishes as design progresses, commensurate with the more detailed methods of forecasting utilised at the later stages. Sixty-five per cent of quantity surveyors consider the level of uncertainty associated with price data used at the inception stage to be unacceptably high. Only at the design concept stage do the majority of practitioners (83%) consider the presence of uncertainty to be within an acceptable limit. Thus, *approximately 20% or more of quantity surveyors consider the presence of uncertainty associated with price data to be unacceptably high until the termination of the design concept stage*.

Given that quantity surveyors exhibit clear preferences for in-house data (Bowen, 1993), one cause of this uncertainty could be the `distortion' that data undergo in their transformation from the information utilised by the contractor's estimator to those reflected in bills of quantities and elemental analyses. Quantity surveyors were asked to rate the distortion of data resulting from the transformation process. The results are shown in Table 5.

Table 5 Distortion of price data during the transformation process

Form of data	Frequency of occurrence		
	Very High / High	Acceptable	Little / None
	(%)	(%)	(%)
Price analyses	19	63	18
Bills of quantities	15	36	49

Price books	59	30	11
Price lists	27	55	18

Quantity surveyors are clearly of the opinion that in-house data undergo less distortion than other forms of data. The finding relating to the use in price forecasting of in-house data compared with other forms of data, supports this contention. At least 15% of practitioners see in-house data as undergoing an unacceptably high level of distortion during the transformation process. *With the possible exception of price data derived from bills of quantities, the majority of respondents see price data as having undergone a transformation, albeit within acceptable limits in many instances*.

3.3 The treatment of uncertainty in the provision of price advice

Having established the presence of uncertainty in the price forecasting process, and having addressed the issue of the uncertainty attached to price data, it is necessary to examine the extent to which quantity surveyors make provision in the price forecasting process for the treatment of this uncertainty. Of relevance here is the fact that, in the opinion of quantity surveyors, *the majority of clients (51%) and architects (60%) do not request an assessment of the uncertainty associated with building price advice*. Notwithstanding this fact, *the majority of clients (86%) and architects (86%) assert that, in the provision of price advice, the presence of uncertainty is acknowledged by the quantity surveyor*. The manner in which the presence of uncertainty is acknowledged was not elicited. However, it was established from the majority of architects (93%) that where the presence of uncertainty is acknowledged by quantity surveyors, the *nature* of that uncertainty is communicated to them.

In this section, the factors influencing whether or not provision is made for uncertainty in price forecasting; the potential of traditional price forecasting models to deal with the various types of uncertainty; the techniques used by practitioners for the treatment of uncertainty; and the stages of the design process at which those techniques are implemented, are examined.

The opinions of quantity surveyors were sought regarding the factors determining whether or not cognisance is taken of uncertainty in the provision of price advice.

Table 6 Factors influencing the extent of the treatment of uncertainty in the provision of price advice

Factor	Frequency of influence		
	Always / Frequently	Occasionally	Seldom / Never
	(%)	(%)	(%)
Price of project	61	16	23
Lack of expertise	28	29	43
Size of project	64	18	18

Type of client	46	30	24
Financial viability	40	29	32
Client sophistication	48	25	27
Time available	46	23	31

With the possible exception of lack of expertise on the part of quantity surveyors, all factors are deemed by respondents to influence whether or not uncertainty is taken into account in the provision of price advice. As many as 28% of respondents consider lack of expertise in this sphere to be always or frequently of influence. The two major categories of influencing factors appear to be the project *per se* (price and size) and the nature of the client (type and sophistication). Unexpectedly, as many as 40% and 46% of respondents, respectively, claim that the `cost-effectiveness' of providing this service and the time available are frequently or always influencing factors.

Table 7 Potential of price forecasting models for handling uncertainty

Model type	Potential of forecasting model for handling uncertainty					Number of respondents
	Very good	Good	Acceptable	Poor	Very Poor	
	(%)	(%)	(%)	(%)	(%)	(No.)
Functional unit	5	0	22	44	30	64
Superficial	2	6	31	46	14	93
Cubic	0	5	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
Bills of quantities	75	20	3	1	1	94
Lump sum	6	3	18	59	15	68
Comparative forecasts	6	15	56	21	1	78
Regression models	8	11	33	39	8	36
Interpolation	0	4	51	36	9	47
Expert systems	9	17	49	17	9	35

Table 8 Ranking of models' ability to handle uncertainty

Model type	Option `1' (%)	Rank `A'	Options `1'+`2' (%)	Rank `B'	Options `1'+`2'+`3' (%)	Rank `C'	Total `A'+`B'+`C'	Final ranking
Bills 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	75	5	13	4

Comparative forecasts	6	7	21	5	77	4	16	5
Regression models	8	5	19	6	52	8	19	6
Storey enclosure	3	9	19	7	56	6	22	7
Lump sum	6	6	9	8	27	11	25	8
Superficial	2	10	8	9	39	9	28	9
Functional unit	5	8	5	10	27	10	28	10
Interpolation	0	12	4	12	55	7	31	11
Cubic	0	11	5	11	16	12	34	12

Thus, *the extent of the treatment of uncertainty in the provision of price advice is seen mainly as a function of project and client characteristics*. Quantity surveyors' assessments of the potential of the various price forecasting methods for handling uncertainty were elicited. In order to rank the perceived ability for handling uncertainty, the *actual* assessment of respondents was required, necessitating the exclusion of the option `don't know'. The remaining responses were then adjusted, and are presented in Table 7.

To facilitate the ranking process, the options `very good', `very good and good' and `very good, good and acceptable' were summed and ranked individually. The three resultant rankings were then summed and divided by three to obtain the final ranking of quantity surveyors' assessments of the potential of price models for handling uncertainty. The ranking process and final rankings are shown in Table 8.

It is evident that quantity surveyors consider bills of quantities to possess the most potential for the handling of uncertainty in the provision of price advice. However, although bills of quantities are ranked first, *the results indicate little difference between the perceived potential of bills of quantities, approximate quantities, and elemental price forecasting methods*. Worthy of note is the apparent relationship between perceived ability for handling uncertainty and the stage at which various models are applied during the design process. For example, *it has been established that the forecasting method most widely applied at the inception stage is the superficial method, the method ranked fourth only to the cubic method for its lack of ability for handling uncertainty*.

In an endeavour to establish the *actual* methods used by quantity surveyors in the *treatment* of uncertainty in price forecasting, respondents were presented with ten techniques drawn from traditional decision theory and requested to indicate the extent of their usage of those techniques. The results are shown in Fig. 6. *These results indicate that the majority of quantity surveyors never use Bayesian theory, fuzzy logic, decision tables, payoff tables, certainty factors or simulation techniques for the quantification of uncertainty*. Probability theory, possibility theory, maximum/minimum ranges and risk analysis are claimed to be used at least occasionally by 57%, 30%, 53% and 34% of quantity surveyors, respectively. However, the use of price ranges is not actually a technique for handling uncertainty, but rather a means of communicating the presence of uncertainty.

The opinions of clients and architects largely agree with those of quantity surveyors, with the majority of both groups stating that the methods used, at least occasionally by quantity surveyors, include probability theory and price ranges. An interesting anomaly is the fact that the majority of clients claim that quantity surveyors at least occasionally use the fuzzy logic (64%) and risk analysis (58%) methods of quantifying uncertainty. These results are in conflict with the opinions of quantity surveyors themselves.

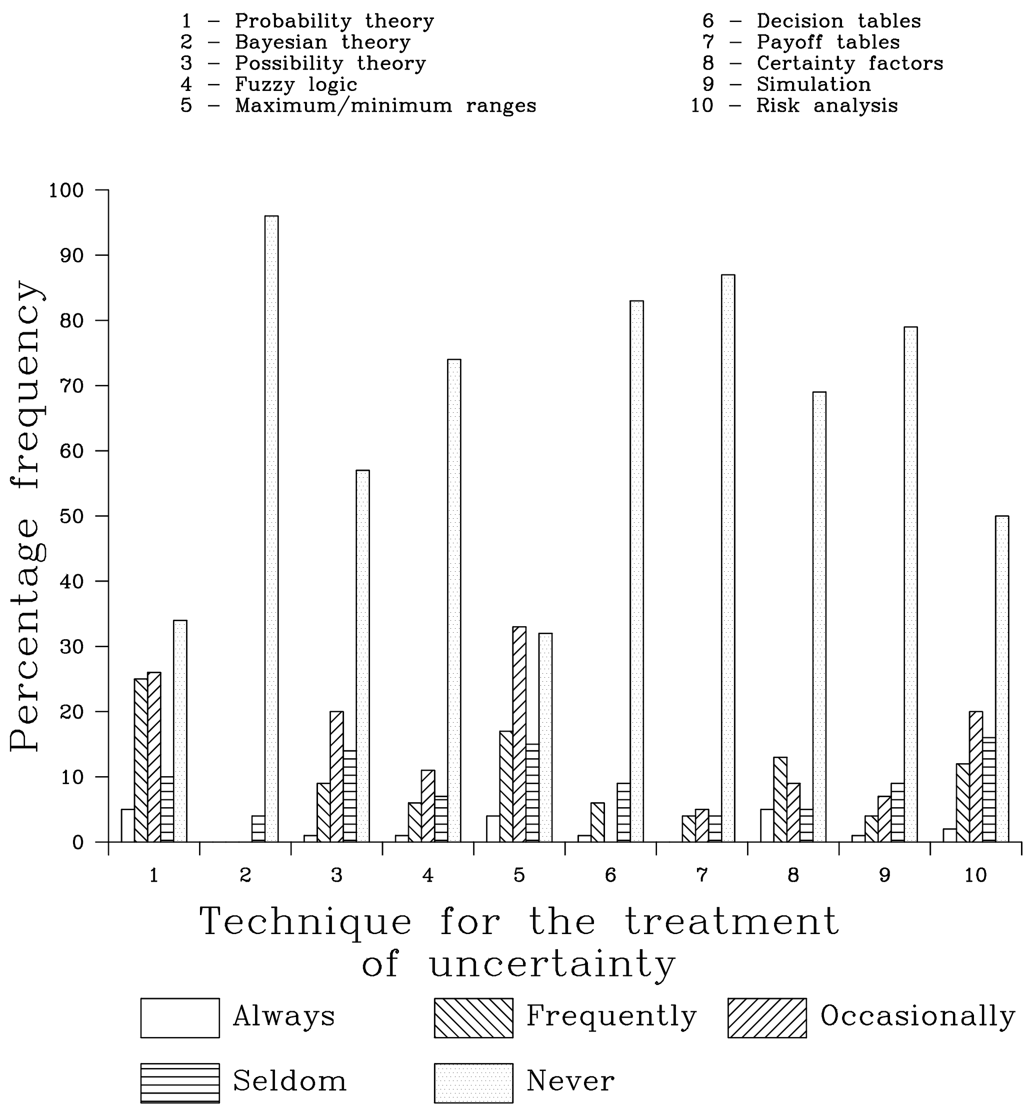


Fig. 6 Techniques utilised by quantity surveyors for the treatment of uncertainty

Thus, *little provision is made for the treatment of uncertainty in price forecasting but, where it is made, probability methods and price ranges are the two techniques most frequently employed by quantity surveyors to quantify the presence of uncertainty.*

Notwithstanding these individual results, given the fact that all the techniques except price ranges and Monte Carlo simulation require extensive mathematical manipulation, it is questionable whether in fact quantity surveyors *actually* utilise these techniques or are even familiar with their mechanics.

Quantity surveyors were requested to indicate the stages of the design process at which they implement methods for dealing with uncertainty. These results are depicted in Fig. 7.

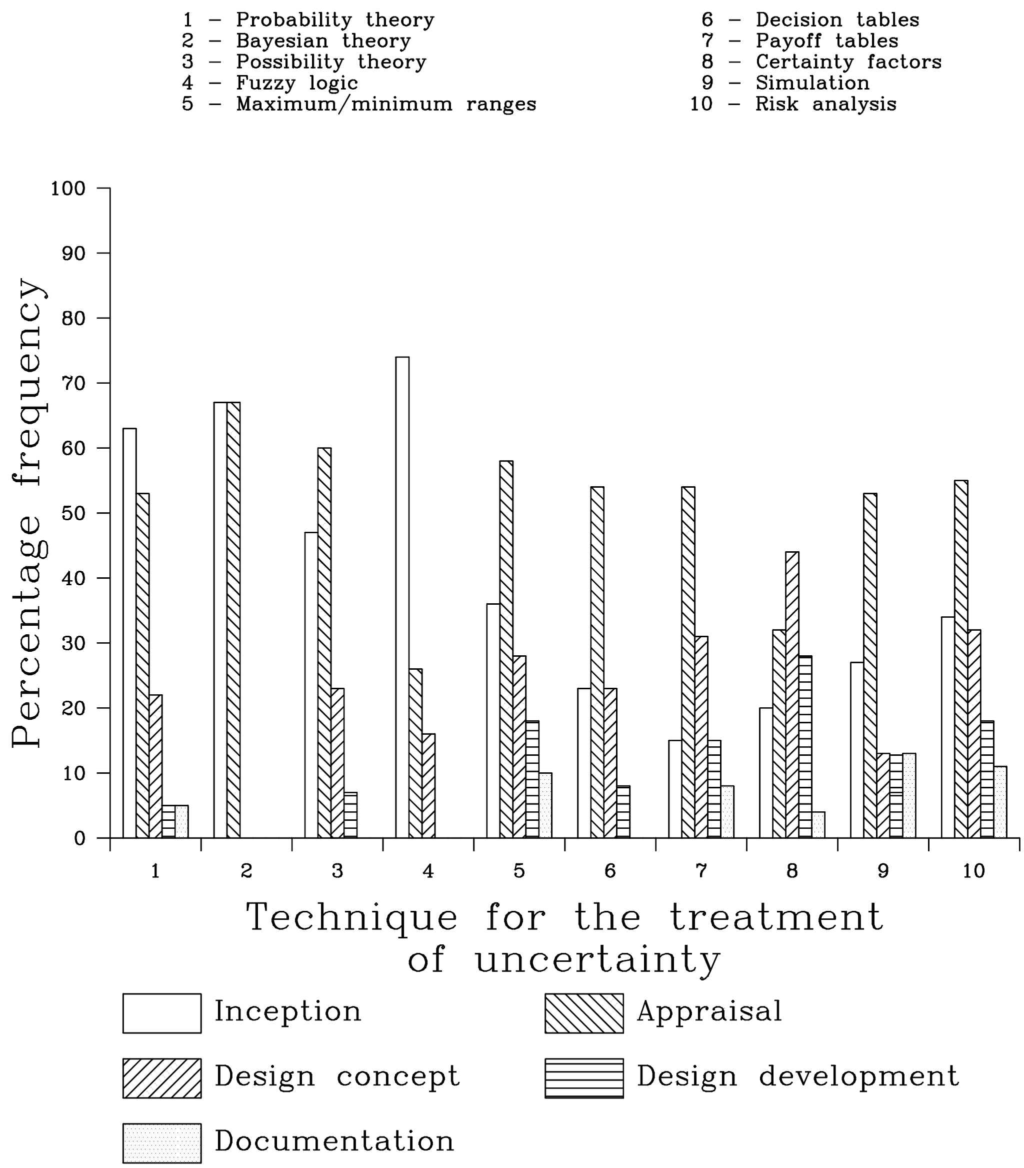


Fig. 7 Stages of the design process at which techniques for handling uncertainty are implemented

It has been shown that probability methods and price ranges are the two techniques most frequently employed by quantity surveyors to quantify the presence of uncertainty in price forecasts. Figure 7 illustrates that these techniques are most widely utilised at the inception and appraisal stages of the design process.

The results depicted in Fig. 7 should, however, be treated with circumspection as they are not considered truly representative given the small sample size from which certain statistics are derived. For example, the number of responses received in respect of Bayesian theory, fuzzy logic, decision tables and simulation techniques were 3, 19, 13 and 15, respectively.

The majority of respondents appear to employ techniques for the treatment of uncertainty predominantly at the inception and appraisal stages of the design process, the stages at which the presence of uncertainty is considered the most widespread.

To summarise, the presence of uncertainty in price data used for price forecasting is considered by quantity surveyors to be unacceptably high until the design concept stage. In-house data, the data preferred by quantity surveyors for price forecasting purposes, are seen as undergoing less distortion in the transformation process than other forms of price data. The presence of uncertainty is usually acknowledged by quantity surveyors in the provision of price advice, notwithstanding the fact that most clients and architects report that they do not request such an assessment. The extent of the treatment of uncertainty in the furnishing of price advice is seen mainly as a function of project and client characteristics. The price forecasting methods of choice, namely, bills of quantities, approximate quantities and elemental price forecasting are considered the most suitable price forecasting methods for the treatment of uncertainty. Little formal provision is made for the treatment of uncertainty in price advice, with price ranges appearing to be the method of choice.

3.4 The communication of uncertainty in the provision of building price advice

The potential for the existence of uncertainty, in terms of the variable nature of the inputs to price models, has been discussed. Clearly, the output of the model should reflect in some manner the existence and quantification of that uncertainty. This, it is believed, will contribute towards more realistic, better informed decisions. Indeed, it was shown in a structured interview survey (Bowen, 1993) that the majority (80%) of users of price forecasts contend that risk and uncertainty *should* be the subject of explicit quantification. The majority (80%) of quantity surveyors agreed.

The communication of the uncertainty associated with price forecasts needs to be done in a manner commensurate with the level of understanding of the user. This will necessitate audience analysis on the part of the quantity surveyor, and hence the formulation of a message suited to the receiver's ability. The complex statistical treatment of uncertainty may be inappropriate to all but the most sophisticated of users. Notwithstanding, *the uncertainty associated with the model output needs to be communicated* in an appropriately formulated price message. The use of histograms and graphs is one possibility for communicating the stochastic nature of output. Another option lies in the provision of price ranges and the likelihood (`p') of a tender price not exceeding the `best' forecast. This could be done orally at several different levels of audience sophistication.

The interpretation of the model output by quantity surveyors is seen as a function of their familiarity with, and faith in, the modelling technique employed. A disadvantage associated with the increasing sophistication of modelling techniques and the use of computers is that the quantity surveyor can become increasingly removed from the modelling technique. This distancing places a greater burden on the ability of the quantity surveyor to interpret the output in a meaningful manner. In essence, a contradiction exists - the distancing of the quantity surveyor from the modelling technique is a barrier to the intrapersonal communication process as convergent thinking is seen as necessary for achieving understanding and meaning i.e., *a distancing/convergence polemic*.

4.0 Conclusions

This paper has considered the problem of uncertainty in building price forecasting, with special emphasis on price data considerations. Clearly, given the uncertainty inherent in the price forecasting process, a deterministic approach to the provision of building price advice is unacceptable. Traditional price modelling techniques take little or no account of uncertainty, confining themselves to determinism of input and output. Moreover, practitioners have largely ignored the implications of uncertainty in the provision of price advice. Attention needs to be given to the incorporation of techniques capable of the explicit treatment of uncertainty. In addition, practitioners need to communicate the nature and extent of uncertainty to recipients of price advice in a manner commensurate with their level of understanding.

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