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A survey of current cost estimating practices in the UK

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The results are documented of an investigation into current cost estimating practices of contractors for construction projects. A questionnaire survey of contractors was undertaken, in which the respondents are classified into four groups based on their turnover namely: very small, small, medium and large firms. The survey indicates that contractors, irrespective of size, continue to undertake cost estimating predominantly for construction planning purposes, including the preparation of tenders and cost control of projects during the execution stage and, to a lesser extent, for construction project evaluation. Recent developments in cost estimating methods and tools that consider risks and variability in cost estimates, such as the use of range estimating and parametric estimating techniques, have not been adopted by contractors. The practice of cost estimating does not differ from conventional techniques based on the use of labour and material constants to obtain prices for bills of quantities items on an item by item basis. The study shows that the major causes of inaccuracy in cost estimating continue to be the lack of practical knowledge of the construction process by those responsible for the estimating function, insufficient time to prepare cost estimates, poor tender documentation and the wide variability of subcontractors' prices.

Keywords: Cost estimate, tendering, performance appraisal, estimating techniques, analysis of variance

Introduction

Cost estimating is the technical process of predicting costs of construction (CIOB, 1983). Generally it is recognized that cost estimating by construction contractors is geared towards the pricing of bills of quantities that are prepared in accordance with a standard method of measurement. Law (1994) has documented a general procedure for building contractor cost estimating. However, he reckoned that in practice, contractors devise their own methods of cost estimating and bidding. Hegazy and Moselhi (1995) have argued that often these methods are inaccurate and unstructured and are based solely on contractors' own experiences and the general-purpose procedures dictated by the software systems they use. Carr (1989) identified a serious lack of generally accepted estimating guidelines, despite the availability of literature on the format, procedures and principles involved in cost estimating.

The construction literature on cost estimating has produced a theoretical basis for the principles involved in the process of cost estimating. However, there appears to be a dearth of literature relating to the practice of cost estimating. The present study examined, by means of empirical analysis, the cost estimating practices of various categories of contractor. More specifically, the study examined uses and techniques of cost estimating and causes of inaccurate cost estimates, and also it documents the general opinions of construction contractors on the shortcomings of cost estimating currently being practised.

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Overview of cost estimating practice

The cost estimating function, an important element in the contractors' bidding process, provides a basis for the contractor to submit a tender sum for a project. Skitmore and Wilcock (1994) have contested (after Fine, 1974) that the assumption that tender prices are based on builders' estimates of future expenditure is questionable. Fine (1974) has argued that tender prices are based on the character of the finished product rather than the processes involved in producing the product. In support of this argument, evidence has shown that estimators try to avoid the real problems of their trades (uncertainty of estimates) by presenting socially acceptable forecasts (Skitmore and Wilcock, 1994).

Most published literature relating to estimating, particularly textbooks, concentrates on the principle and process involved in the function of estimating. It would appear that the process has suffered the shortcomings that could be expected given the extreme competition that is involved in construction bidding and the limited understanding of the underlying drivers of construction cost performance. Uman (1991) contends that it is difficult to develop a standard process from which to develop a cost estimating system for construction, due to such factors as extreme diversity in building systems, methods, projects, suppliers, contractors and workforce. Bennett and Barnes (1979) had contended that ideal cost models cannot be developed as the actual costs of construction will depend on many factors, including contractors' individual selection of construction resources and methods, and the timing and sequence of operations.

Based on a case study approach, Green (1989) identified factors considered by contractors' estimators in pricing a bill item, the number of these factors that are included in the item and how many are accounted for elsewhere, all of which are dependent upon the pricing policy of the individual company concerned. Hegazy and Moselhi (1995), based on a questionnaire survey, produced a research report on the elements of cost estimating in Canada and the United States. The research investigated relationships between mark-up and competition, need for work and contract duration, and variations between contractors' estimates of different cost elements. The report indicated that direct cost and project overheads are estimated by contractors in a detailed manner, but not so in the case of general overhead costs and the mark-up, due to the high level of uncertainty and lack of adequate decision support tools. The work recommended that a set of estimating standards should be established and that more effective decision-support tools for estimating purposes should be developed.

Cost estimating methods have been developed for preparing estimates of various types and for various purposes (Daschbach and Apgar, 1988). Many standard textbooks on cost estimating (e.g. Bentley, 1987; Buchan *et al.*, 1991; Kwakye, 1994; Smith, 1995) are readily available. Law (1994) documents a systematic procedure, format and methods involved in UK building contractor estimating in relation to labour, plant, material, subcontractors, overhead and profit. Alternatively, the components of the cost estimate can be grouped into either direct and indirect cost or variable and fixed costs (Carr, 1989). Ntuen and Mallik (1987) have identified techniques or modelling tools for cost estimating which are classified into four groups: experienced based (algorithms, heuristics, expert system programming); simulation (heuristics, expert models, decision rules); parametric (regression, Bayesian, statistical models, decision rules); and discrete state (linear programming, classical optimization, network, PERT, CPM).

Daschbach and Apgar (1988) and Shash and Al-Khaldi (1992), for example, have documented the use of parametric cost estimating techniques such as simple arithmetic formulae and statistical formulae. Groen and Tan (1977) produced a detailed application of cost factor estimating, while Klumpar (1990) has shown how cost estimates could be produced based on capital cost estimation. This method of capital cost estimation, based on correlation techniques, uses a combination of material, labour and plant cost factors to produce an installation cost for manufacturing equipment. Considering that the estimating of a construction project is time consuming and often tedious, and to improve the quality of the estimate, Bryan (1991) advocates the use of an assembly pricing technique (also called work module pricing, system pricing, rapid pricing or aggregate pricing). This method presents costs in composite pieces that can be related easily to the drawings.

Although most of the contractors use the standard estimating procedure, Beeston (1983) has advocated a simple procedure to improve estimating performance involving the use of several methods for each estimate and maintaining records which allow contractors to select the best method or combination of methods.

Vergara and Boyer (1974) have argued that the precision of estimates depends not only on the method but also on the type of work and on the intended use of the estimate. They are of the opinion that to increase the reliability of estimates, the level of detail involved should be increased up to a limit (optimum level of detail) at which the cost of increased reliability equals the value of the increased reliability. Because of the time and cost constraints associated with this practice

they have advocated a probabilistic approach to cost estimating.

Shash and Al-Khaldi (1992) have identified factors affecting the accuracy of cost estimating; these are classified as financial issues, bidding situations, project characteristics and the estimating process itself. The main factor identified in the study by Shash and Al-Khaldi (1992) as responsible for the accuracy of cost estimates, irrespective of the size of contractors, was previous experience of the contractor on the type of project. This factor was followed by anticipated or frequent delays in periodic payments, type and size of contract and project location.

The study by Al-Harbi *et al.* (1994) shows that the major problems facing cost estimators in preparing cost estimates, in order of importance were: tough competition, contract period, incomplete drawings and specification, incomplete project scope definition, unforeseeable changes in material prices, changes in owners requirements, current workload, errors in judgement, inadequate production time data, lack of historical data for similar jobs and lack of experience in similar projects.

Study methodology and sample coverage

Questionnaire design

The questionnaire survey was undertaken to determine the opinion of contractors regarding current estimating practices in the UK construction industry. A six-page questionnaire, accompanied by a covering letter, was sent to the managing directors of sample firms. The letter indicated the objectives of the research and requested that the questionnaire should be completed by a senior staff member responsible for cost estimating activities in the firm.

The questionnaire design was based on a combination of an extensive review of the literature dealing with cost estimating and the authors' general knowledge of cost estimating practice in the United Kingdom. The final questionnaire was developed with the aid of a series of pilot studies involving the estimating directors of three construction contractors (small, medium and large firms).

Sample design

The questionnaire was mailed to 200 firms, the selection being based on a combination of random and quota sampling methods. Firms were randomly selected from available lists of contractors including the *Directory and Handbook of Chartered Building Companies*, published by the Chartered Institute of Building, and the *UK Directory of Construction Industry*, published by Building Economics Bureau Ltd, Bromley, Kent.

It was posited initially that differences in estimating practices would be found among different size grouping of contractors. As a result, four groups were identified based on annual turnover for the purpose of data collection, analysis and results presentation. Watt (1980) points out that the size of a company can be measured in terms of number of employees, net assets (capital employed), value added (net output) and turnover. The random sampling was complimented by a quota sampling method from which 50 questionnaires were mailed to each of the four groups.

After preliminary analysis of the data the number of usable questionnaires for analysis amounted to: 25 from very small firms; 26 from small; 16 from medium; and 17 from large firms. Overall, a total of 84 firms returned completed questionnaires in a usable format, representing a 42% response rate. The response rate was considered high compared with the norm of 20–30% with most postal questionnaire surveys of the construction industry. Vidogah and Ndekugri (1998) received a 27% response rate to their survey questionnaire and Shash (1993) 28.3%. The response rate is typical of a construction industry questionnaire survey and cannot be regarded as biased considering Moser and Kalton's (1971) view that the results of a postal survey could be considered as biased and of little value if the return rate is lower than 30–40%.

Table 1 shows the firms' grouping and the number of firms in each group. From this distribution of the respondents it can be concluded that the survey covers a spectrum of very small, small, medium and large construction contractors in the UK industry. Subject to the limitations of the sampling method, the firms surveyed represent a reasonable proportion of the UK construction contractors population. The total turnover of the firms surveyed (£5842 million) represents 10% of UK contractors' output for 1997.

Characteristics of the respondents and responding firms

Most respondents occupy senior management positions within the firms with an average term of construction experience of about 28 years (standard deviation = 8.6) and are responsible for cost estimating functions. Moreover, the respondents have been in their current firms for long periods, presumably being *au fait* with the practice of cost estimating in their respective firms (overall mean = 16 years, standard deviation = 10). Most respondents have basic academic qualification such as a Bachelor of Science degree, Masters degree, Diploma or professional qualifications of professional

Table 1 Frequency distribution for the responding companies

Groups	Turnover (£m)	Frequency	Percentage	Sum (£m)	Mean (£m)	Std dev (£m)
Very small	Less than £5	25	29.8	49.85	1.99	1.46
Small	5–25	26	31.0	360.20	13.85	6.12
Medium	25–100	16	19.0	792.00	49.50	21.33
Large	Over 100	17	20.2	4640.00	272.94	156.06
	Total	84	100	5842.05	69.55	125.24

bodies such as The Royal Institution of Chartered Surveyors, Chartered Institute of Building, Chartered Institute of Engineering, all of which are relevant to cost estimating functions. Based on position, work experience and educational and professional background, it is reasonable to infer that respondents have adequate knowledge of the activities associated with construction cost estimating.

Table 2 shows the workload of the firms involved in the survey. The main workload of the majority of the very small firms (95%) and small firms (94%) is building work, in contrast to medium and large companies with some significant proportion of civil engneering work (27% and 33%, respectively). The implication is that the cost estimating practices employed by the medium and large companies, as presented in this paper, could be regarded as being relevant to civil engineering works.

Data analysis and results

Respondents were presented with lists of cost estimating practice issues (such as the uses of estimating, estimating techniques and causes of inaccuracy in cost estimating) and requested to rate them on a 5-point Likert scale in terms of the extent to which the estimating techniques are used or the importance of use of cost estimating, with '5' indicating 'high extent' or 'most important' and '1' indicating 'least extent' or 'least important'.

Data analyses were undertaken using the Statistical Package for the Social Sciences (SPSS). The analyses deal mainly with the ranking of the variables based on their mean values. This is followed by comparison of mean values for the groups and by analysis of variance (ANOVA) to test the null hypothesis that the mean values of the dependent variable are equal for all groups. The ANOVA provided the opportunity to clarify whether or not the opinions of the contractors' groupings are the same or not for cost estimating practice variables.

Table 2 Mean percentage of the firms' workload

Workload	Overall	Very small	Small	Medium	Large
Building work	82.51	94.60	93.96	71.19	57.82
Civil Engineering work	12.71	1.00	1.62	27.19	33.29
Others	4.77	4.40	4.42	1.56	8.88

The reliability of the 5-point Likert scale measurement was determined using Cronbach's coefficient alpha. This measures the internal consistency among the items on each factor, and the results were in the range 0.606–0.899. This is considerably higher than the modest reliability in the range 0.50–0.60 suggested by Nunnally (1978) as sufficient for this type of research.

Uses of cost estimating

Available cost estimating techniques range from extremely detailed cost breakdowns, particularly those based on bills of quantities, to overall cost analyses used for comparison and control purposes (Uman, 1990). Table 3 shows construction contractors' use of cost estimating. It is expected that responses relating to the use of cost estimating will provide the rationale for the cost estimating procedure. The Cronbach's coefficient alpha was 0.76, which is considered acceptable for scales of this kind.

Cost estimating within the firms is used predominantly to prepare tenders for clients, monitor project execution and audit project success. The study revealed that the main use of cost estimating for the subset groups is for tender sum preparation in response to an invitation to bid by construction clients. Table 3 suggests also that cost estimating is used more for project control and planning than for evaluation. These results are similar to the study of the use of cost estimating for information systems software cost estimating practice produced by Lederer and Prasad (1993).

The overall rating of 3.237 for staffing the project (see Table 3) was lower than 4.012 for auditing the project success at the 0.05 level of significance ($p = 0.002$). This suggests that the importance of use rating for each of the three top uses was significantly higher than for the lower uses at the 0.05 level of significance. Moreover, according to Lederer and

Table 3 Uses of cost estimate[a]

Use	Overall	Very small	Small	Medium	Large	*F* stat.	Sig. *p*
To prepare tender for client	4.461	4.417	4.692	4.750	4.824	1.049	0.376
To control or monitor project execution	4.048	3.708	4.000	4.250	4.412	1.371	0.258
To audit project success	4.012	3.750	4.192	4.000	4.118	0.750	0.526
To staff project	3.247	3.083	3.292	3.313	3.353	0.222	0.881
To schedule projects	2.987	2.875	2.739	3.375	3.133	0.957	0.418
To select projects to tender for	2.913	3.087	3.000	3.063	2.375	0.905	0.443
To evaluate project estimator	2.704	2.667	2.840	2.938	2.313	0.810	0.492
To evaluate client	2.468	2.609	2.542	2.313	2.313	0.287	0.835

[a] Reliability coefficient (Cronbach's alpha) = 0.7602.

Prasad (1993), the division of the table into the two parts suggests that estimating is used insignificantly for evaluation. Since evaluation is tied to improved performance (Lawler *et al.*, 1984), the lesser use of cost estimating for evaluation may provide an account for the inaccuracy in cost estimates.

Table 3 suggests also that there is no difference of opinion in the use of cost estimating by the very small, small, medium and large firms at the 5% significance level.

Techniques of cost estimating

Table 4 shows the techniques used in cost estimating by the firms. The three main methods used for cost estimating are estimating standard procedure (overall mean = 4.869), comparison with similar projects based on documented facts (overall mean = 3.643) and comparison with similar projects based on personal experience (overall mean = 3.619). The mean values for these methods were higher than the next method (established standard with overall mean = 2.679) and other methods in the table at the 0.05 level of significance. These three most popular methods are within the domain of what Ntuen and Mallik (1987) called 'experience-based' models. The intuition method was ranked 5th overall, although this was ranked in 4th position by both the very small and small contractors.

The main method being used by the companies is the standard estimating procedure which is found in most estimating textbooks, where the costs of construction (labour, material, plant, subcontractors) are established and to which an allowance for overheads and profit is added. The procedure emphasizes that the estimate is prepared in a logical manner based on information on historical costs and anticipated production outputs during construction on site. However, the

Table 4 Techniques for cost estimating[a]

Technique	Overall	Very small	Small	Medium	Large	*F* Stat.	Sign.
Estimating standard procedure	4.869	4.800	4.923	4.938	4.824	0.723	0.541
Comparison with similar past projects based on personal experience	3.619	3.680	3.654	3.500	3.588	0.110	0.954
Comparison with similar past projects based on documented facts	3.643	3.600	3.577	4.063	3.412	1.159	0.331
Establish standards	2.679	2.640	2.769	3.000	2.294	0.854	0.469
Intuition	2.551	2.700	2.808	2.267	2.235	1.557	0.207
A simple arithmetic formula	2.512	2.833	2.769	2.200	1.941	2.441	0.071
Usage of software for estimating	2.714	1.720	2.192	3.250	4.471	15.154	0.000
Published price information	2.060	2.360	2.039	2.000	1.706	1.690	0.176
Capital estimating factors	1.929	2.040	2.039	1.938	1.588	0.405	0.750
Shared information with subsidiary of the firm	1.768	1.120	1.833	2.188	2.235	6.600	0.000
Range estimating (based on probabilistic technique)	1.651	1.760	1.680	1.438	1.647	0.364	0.779
Guessing	1.536	1.680	1.539	1.438	1.412	0.367	0.777
Shared information from other construction firms	1.381	1.200	1.346	1.625	1.471	1.527	0.214
A complex statistical formula	1.241	1.080	1.120	1.500	1.412	2.087	0.109

[a] Reliability coefficient (Cronbach's alpha) = 0.6062.

input forming the basis for this method of estimating has been criticized for its wide variability (Beeston, 1983; Ashworth and Skitmore, 1983).

Cost estimates produced using the top-ranked three methods are deterministic in nature (single-point number). Curran (1989) has argued that these 'conventional or traditional' methods of estimating often fail to cope with the realities of today's world, which involves elements of uncertainty. Due to the risk of overestimating or underestimating, Curran (1990) has suggested the use of range estimating by contractors as part of their estimating process. Range cost estimating techniques combining Pareto analysis, heuristics and Monte Carlo simulation, eradicate or at the least significantly reduce the risk associated with cost estimates. In essence, the range estimating approach can be described as a decision support technique, which is an adjunct to traditional estimating. Range estimating could provide information on the probability of a cost overrun, on how large the overrun can be, and on what to do to eliminate or reduce cost overrun risk, including how much contingency to add to the estimate in order to reduce any residual risk to an acceptable level.

In addition, Table 4 shows that range estimating, parametric estimating, and factor estimating are not popular with construction contractors. The fact that parametric estimating is not used by contractors could be because it is not intended for the creation of detailed estimates (Koenigseker, 1982). However, since it is useful to establish an order of magnitude project value and helpful when time is at a premium, this method could assist contractors to verify the accuracy of their detailed cost estimates produced by any of the conventional techniques, and to determine the approximate value of the project in order to make a decision whether or not to tender for the project. Various reasons could be responsible for contractors not using other groups of cost estimating methods defined by Ntuen and Mallik (1987). For example, the study by Akintoye and MacLeod (1997) documented some reasons why construction contractors are not using simulation techniques, including Monte Carlo, for construction risk management, which can be regarded as being relevant to cost estimating practice. The reasons include: (a) lack of familiarity with the techniques; (b) the degree of sophistication involved in the techniques is unwarranted for project performance; (c) time plus lack of information and knowledge; (d) doubts whether these techniques are applicable to the construction industry; (e) most construction projects are seldom large enough to warrant the use of these techniques or research into them; (f) they require availability of sound data to ensure confidence; and (g) the vast majority of risks are contractual or construction related and fairly subjective, and hence they are dealt with better on the basis of experience from previous contracts undertaken by the firm.

Cost estimating software could be used for various reasons including the need to relieve the estimator of the continual task of manually and mentally building-up rates; to increase the time available for the function including consideration of methods of construction for the project, to achieve better cost data analysis, storage and manipulation, etc. Cost estimating software, usually embodying the traditional cost estimating methods, is used by medium and large contractors (mean = 3.250 and 4.471, respectively), which is significant at 5% level ($p = 0.000$) compared with the other two groups of contractors. The computerized traditional estimating has the advantage that it enables a more realistic range of cost estimates to be generated quite easily by applying sensitivity analysis. However, unlike the simulation techniques, it does not provide any information on the probability of the outcomes.

Other significant results, below the 10% level, include the fact that the small contractors have a tendency to use simple arithmetical methods to prepare cost estimates compared with the large firms; while large firms have subsidiaries with whom they can share cost information or who can contribute some cost input to their cost estimate. It is not unusual for large construction firms to have specialist subsidiaries that act independently of the parent company or as subcontractors to their parent company. This is part of the diversification that the construction industry has witnessed in recent times in order to sustain the profitability of the parent company.

Shared information with other construction firms as a preferred estimating technique was ranked at the bottom of the list, below guessing. This is not unexpected given that construction tendering is significantly based on fierce competition. That apart, most tender documents specify that any evidence of collusion between competing contractors on a contract will invalidate their bids. Given the competitive nature of tendering, it is natural to expect that most contractors are unlikely to share any information that may give them a competitive advantage over their competitors.

Many books (e.g. Laxtons, Spon, Griffiths, Wessex, Hutchins Priced Schedule, Cost Datafile, etc.) are available to assist in pricing of construction projects. Table 4 shows that they are used minimally by contractors (ranked 8th overall), although they find more use by very small contractors. This result is not unexpected given that cost information published in the price books often show wide variability. For this one reason, price books may not be appealing to large contractors pricing construction projects. Although factors such as complexity of design and construction,

scale and scope of construction, method or technique of construction, etc. (Akintoye, 1999) have an influence on cost estimating practice, price books do not contain information on these factors, and this may be another reason why they are not used to a greater extent by large contractors. Large contractors must give adequate attention to such factors in their cost estimates in order to submit competitive tenders in terms of cost, time and quality. It is possible, however, that large contractors use this source of cost information to cross-check their own pricing levels. For small contractors unable to afford appropriate estimating personnel and due to the nature of their work, it is reasonable to expect that they should depend on price books for the preparation of cost estimates.

Causes of inaccurate cost estimates

Table 5 depicts the contractors' opinions regarding the factors responsible for inaccurate cost estimating. The most important factor is insufficient time for cost estimating, followed by poor tender documentation and insufficient tender document analysis by the estimating team. Generally, these factors were rated more highly by small contractors compared with large contractors.

One major factor responsible for inaccurate cost estimating recognized by Carr (1989) is estimating for projects in an area in which the estimators have little knowledge. This is ranked highly by the contractors relative to poor understanding of project requirements by estimators, which was ranked in fourth position.

Other causes of inaccurate cost estimates are perceived to include poor communication between the estimating team and construction team, low participation in the estimating function by the site team that will be responsible for the construction, and lack of review of cost estimates by company management. Generally, however, large contractors rated the causes of inaccurate cost estimates lower than the other groups. This suggests that large contractors do not have much problem with cost estimating functions, perhaps because the cost estimating and tendering departments within large contractors are well organized with clearly defined responsibilities and activities. In addition, most large contractors use cost estimating software which addresses any problems of insufficient time for estimating, poor tender documents, insufficient tender document analysis, etc.

Table 5 Causes of inaccuracy in cost estimating[a]

Causes	Overall	Very small	Small	Medium	Large	*F* Stat.	Sign.
Insufficient time for estimating	3.988	4.292	3.885	4.063	3.647	1.612	0.193
Poor tender documents	3.952	4.125	4.154	3.813	3.629	2.086	0.109
Insufficient tender document analysis	2.829	3.167	2.680	2.813	2.588	1.518	0.216
Lack of understanding of project requirements	2.470	2.417	2.539	2.375	2.529	0.098	0.961
Poor communication between project team	2.470	2.417	2.500	2.563	2.412	0.087	0.967
Low participation in estimating by site team	2.458	2.292	2.769	2.500	2.177	1.363	0.260
Lack of review of cost estimate by management	2.398	2.333	2.192	2.750	2.471	0.840	0.476
Poor comprehension of site requirements	2.361	2.250	2.577	2.563	2.000	1.582	0.200
Poor feedback on accuracy previous estimates	2.333	2.391	2.346	2.133	2.412	0.255	0.858
Pressure from management	2.325	2.583	2.346	2.125	2.118	0.694	0.558
Removal of estimate padding by management	2.293	2.304	2.577	2.438	1.706	2.431	0.071
Poor project cost feedback	2.281	2.375	2.231	2.333	2.177	0.156	0.926
Lack of diligence by estimators	2.277	2.375	2.192	2.563	2.000	0.689	0.561
Lack of adequate guidelines for estimating	2.096	2.333	2.308	1.875	1.647	2.377	0.076
Inaccurate production data used in estimating	2.037	2.125	2.077	1.867	2.00	0.269	0.847
Lack of historical data on past estimates	2.012	2.167	2.039	2.000	1.765	0.556	0.645
Poor analysis of cost data for cost estimate	1.928	2.042	1.923	1.813	1.882	0.301	0.825
Lack of performance reviews of estimators	1.904	1.917	2.000	2.188	1.471	2.055	0.112
Estimators lacks of data processing techniques	1.831	2.083	1.731	1.688	1.765	0.972	0.410
Frequent requests for changing of estimate	1.639	1.792	1.500	1.688	1.588	0.579	0.631

[a] Reliability coefficient (Cronbach's alpha) = 0.8996.

Surprisingly, factors such as inaccurate production data used in estimating, lack of historical data from past estimates and poor analysis of cost data for cost estimating were not ranked highly as the causes of inaccurate cost estimates. Clearly, the responses show that the contractors have attributed the main causes of inaccurate cost estimates to construction clients' requirements rather than accepting some obvious shortcomings of cost estimating departments. For example, it is reckoned that there is a wide variability in the production performance of contractors (Thomas *et al.*, 1992; Naoum and Hackman, 1996). Given that historical production performance data form an input to future cost estimating, it is obvious that inaccurate data will constitute a major cause of inaccurate cost estimates; however, inaccurate production data used in estimating is rated 15th (overall mean = 2.037).

Despite large contractors rating the causes of inaccurate cost estimates generally lower than the other groups, the opinions of the groups (very small, small, medium and large contractors) did not differ on each of the causes of inaccurate estimates, at the 5% level of significance.

Cost estimating practices

Table 6 shows that although most participating contractors prepare detailed cost estimates for both small and large projects, they have more tendency to prepare detailed cost estimates for large projects compared with small projects (t-value = 5.19, $p = 0.000$). This is not unexpected given that large projects tend to constitute a large proportion of most contractors' workload; any underestimation of project costs could affect the firm's profitability significantly. Management of the cost estimating functions for small and large projects, as shown in Tables 7 and 8, respectively, indicates that managing directors of construction firms have most responsibility for the approval of cost estimates for large projects rather than small projects. The approval of cost estimates for small

Table 6 Percentage of projects for which detailed cost estimates prepared

	Overall	Very small	Small	Medium	Large	*F* Stat.	Sign.
Large projects (%)	93.67	90.42	91.53	99.06	96.47	1.347	0.265
Small projects (%)	81.48	71.25	79.58	91.56	89.12	3.713	0.015

Table 7 Company management responsible for approving cost estimate for large projects

	Overall		Very small		Small		Medium		Large	
	No.	%	No.	%	No.	%	No.	%	No.	%
Managing director	75	89	22	88	26	100	12	75	15	88
Estimating director	34	40	11	44	7	27	9	56	7	41
Chief estimator	28	33	5	20	10	38	6	38	7	41
Technical director	16	19	3	12	3	12	6	38	4	24
Others; Commercial director	20	24	1	4	4	15	6	38	9	53

Table 8 Company management responsible for approving cost estimate for small projects

	Overall		Very small		Small		Medium		Large	
	No.	%	No.	%	No.	%	No.	%	No.	%
Chief estimator	44	52	8	32	11	42	13	81	12	71
Managing director	40	48	17	68	14	54	5	31	4	24
Estimating director	32	38	10	40	10	38	8	50	4	18
Technical director	10	12	1	4	2	8	4	25	3	18
Others; Commercial director	19	23	3	12	5	19	2	13	9	53

projects typically could be undertaken by the chief estimator of the firms. Large projects often make great demands on construction firms' resources; it is therefore essential for such projects to receive the approval of the chief executive of the company who has a clearer view of the available resources.

It is unusual for small firms to have a separate cost estimating department, unlike the situation prevailing in medium and large contractors. In a small firm, cost estimating and other management functions of the company are most likely to be performed by a single individual, usually the managing director or proprietor of the firm. This contention is supported by Tables 7 and 8, where approval for cost estimates for both small and large projects is undertaken by managing directors. Because medium and large contractors usually have estimating departments, estimating functions, including the approval of cost estimates, are devolved to senior staff within the estimating department.

Designations of other senior management that have responsibility for approving cost estimates include: area or regional directors, commercial directors or managers, operation directors, purchasing directors, finance directors and small work managers (for small work). Table 9 shows, as expected, that most contractors devote more resources and senior management time to the vetting and approval of cost estimates for large projects than small projects (t-value = 10.36; $p = 0.000$).

Generally, project cost estimating is regarded as a multi-disciplinary function which could involve engineering, financing and management decisions, although this function is coordinated by the estimating department (where available within the firm). Table 10 shows participants for the cost estimating function, with the estimators having overall responsibility. Other major participants include subcontractors, managing directors and contracts managers. Some other participants identified by the respondents include: planning or programming engineers (planners), commercial managers, design engineers, suppliers, cost planners and insurance assessors. In some companies, the estimating manager and estimating director are designated commercial managers and commercial directors, respectively. The involvement of site management in cost estimating is minimal. Table 10 shows also that managing directors in large firms have less participation in cost estimating functions compared with the small firms ($p = 0.009$). Because of the nature and structure of large firms, their organizations tend to have a purchasing department,

Table 9 Extent to which company management study and approve cost estimate

	Overall	Very small	Small	Medium	Large	F Stat.	Sign.
For large projects	4.500	4.208	4.542	4.625	4.750	1.891	0.138
For small projects	3.400	3.500	3.292	3.000	3.813	1.990	0.137

Table 10 Participants in cost estimating

	Overall	Very small	Small	Medium	Large	F Stat.	Sign.
Estimators	4.831	4.875	4.846	4.875	4.706	0.223	0.880
Subcontractors	3.878	3.565	4.192	4.188	3.529	2.534	0.063
Managing director	3.580	4.174	3.692	3.375	2.750	4.115	0.009
Contract managers	3.446	3.792	3.385	3.500	3.000	1.476	0.228
Quantity surveyors	2.380	2.714	2.269	2.438	2.063	1.149	0.355
Site management	2.124	2.130	2.000	2.313	2.118	0.332	0.802
Store managers/buyers	1.739	2.577	3.000	2.235	3.861	3.861	0.013
Others; planners	2.790	1.000	3.800	2.429	2.668	1.062	0.395

Table 11 Extent to which cost estimate is used to evaluate and review performance

	Overall	Very Small	Small	Medium	Large	F Stat.	Sign.
Estimating personnel	2.783	2.720	2.840	2.938	2.647	0.190	0.903
Estimating department	3.037	2.960	3.040	3.188	3.000	0.130	0.942

Table 12 Shortcomings in skills, knowledge and data for cost estimating

Shortcomings	No. of firms
Practical experience	
Lack of site knowledge and construction process by estimators	14
Tender documentation	
Poor tender documentation, particularly BoQ	15
Insufficient time to prepare tender	13
Poor performance of design team in presenting tender document	6
Insufficient information for tender (e.g. for ground work)	3
Subcontracting	
Variability in subcontractors' prices	3
Move from analytical estimating to commercial estimating	2
Inaccurate M & E quotations	1
Estimators are de-skilling, relying on subcontractors to provide the specialist knowledge	1
Poor understanding of how specialist trades are costed and output standards are hardly known	1
Estimating software	
Lack of knowledge of computer applications	1
Proliferation of different cost-estimating software	1
Computerization of cost estimating	1
Cost data	
Lack of actual costs feedback	1
Regional price variations	1
Training and education	
Lack of training	4
Limited number of experienced estimators	1
Lack of estimating as a dedicated subject in college courses	1

which provides data input to the cost estimating process. Table 10 show that buyers and store managers, as part of purchasing departments in large firms, have significant participation in cost estimating functions compared with small firms ($p = 0.013$).

The extent to which the accuracy of cost estimates is used to evaluate and review the performance of estimating personnel and estimating departments generally is small (Table 11). There is no difference in opinion on this issue based on company size ($p = 0.903$ and 0.942, respectively). This tends to suggest that variance in cost estimates is not to be used for performance appraisal of the estimating personnel or estimating department by a construction contractor. If indeed this is the case, then the result could be laxity in the performance of estimating departments, considering the assertion by Newman (1975) that management evaluation of performance increases supervisor and subordinate awareness and inspires performance. Nonetheless, it would appear that management of construction firms has a tendency to use accuracy of cost estimates to appraise estimating departments rather than specific estimating personnel (t-value = 3.28; $p = 0.002$)

General comments on cost estimating practices

The respondents were asked to provide comments on weaknesses in skills, knowledge and data for cost estimating for construction. Not all the respondents replied to this open question. However, the comments offered by some of the participants are summarized and classified in Table 12. They appear under six headings: site practical experience; tender documentation; subcontracting practice; estimating software cost data; and education and training. The main shortcomings identified by the respondents are poor tender documentation, lack of practical knowledge of construction processes by those responsible for the estimating function, insufficient time to prepare cost estimates, and variability in subcontractors prices.

These shortcomings can be regarded as resulting from a combination of the internal and external environment in which the estimating function takes place. Typically, cost estimating is a multi-disciplinary task which is based on historical data and requires input from the design team. A cost estimate is determined by the type of project, and it is associated with changing building materials and technology.

Bennett and Barnes (1979) identified two major features exerting the greatest influence on building costs: the construction technology employed and the relative cost of construction resources. Paradoxically, the respondents identified practical site experience (encompassing construction technology) as an area where the personnel responsible for cost estimating need help. It is a general opinion of the respondents that the quality of tender information provided by design teams is poor. This could be associated with the lack of accurate, meaningful, comprehensive tender information such as schedule of works, specifications, bills of quantities (BoQs) and drawings.

Conclusions

Current views of contractors (very small, small, medium and large) on cost estimating practice were presented. Cost estimating is a factual process designed to predict the cost price of undertaking construction work. This process is based on the practical and tech-

nical knowledge of the estimating, planning and site management teams backed up by data from previous schemes.

The study highlights that construction contractors continue to use conventional or traditional techniques for cost estimating, which entails pricing of construction resources for the project, including labour, materials, plant, subcontractors and overheads. The use of these conventional techniques provides a major reason why cost estimating is used predominantly for planning and to lesser extent as a decision-support technique. Techniques such as range estimating, factor estimating and parametric estimating find little or no application among construction contractors for estimating purposes; this is despite the fact that these could provide useful tools for reviewing detailed cost estimates produced by conventional methods in the shortest time possible.

The study shows that the main shortcomings in cost estimating, which also have been identified as causes of inaccurate cost estimates, are a lack of practical knowledge of the construction process by those responsible for the estimating function, insufficient time to prepare cost estimates, poor tender documentation and a wide variability in subcontractors prices.

Given that the participants have identified practical site experience (encompassing construction technology) as an area where the personnel responsible for cost estimating are in need of help, it is essential that contractors provide an on-site production control training programme for their estimators to gain on-site experience on cost comparison. Considering the views of the respondents, there is an urgent need for both the educational establishments and the professional bodies such as the Chartered Institute of Buildings (CIOB) to review cost estimating practice in terms of education and training required for those responsible for estimating functions. The Procurement Committee of the CIOB recently established a conference of educational institutions that will meet regularly to promote activities which enhance the teaching and learning experiences of students in the subject area of estimating and tendering. The first workshop of the special interest group, entitled Innovation in Teaching of Estimating and Tendering on CIOB Accredited Courses, was held in late 1998. The objectives of the meeting were 'to focus on innovation to promote activities that enhance the teaching and learning experiences of students, and to support lecturers who deliver subjects related to estimating' (Sher, 1998). The activities of the CIOB special interest group are in the right direction; however, practising estimators within the construction contractors' group (representatives of small, medium, large and very large construction firms) should be involved and encouraged to participate in the deliberations of this group in order to achieve cross-fertilization of innovative ideas in tendering and estimating.

Moreover, appraisal of cost estimating is essential to improve the performance of cost estimating personnel and departments. Although the study suggests that few firms are currently undertaking such appraisal, it may be said that because repeated underestimating of projects may lead to the bankruptcy and overestimating prevent the contractor from securing contracts, the need to undertake the appraisal is an imperative. In order to prevent complacency in the performance of both cost estimating personnel and departments, construction firms should develop cost estimating appraisal frameworks which can provide also a benchmark for their cost estimating activities.

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