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Analysis of factors influencing project cost estimating practice

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Although extensive research has been undertaken on factors influencing the decision to tender and mark-up and tender price determination for construction projects, very little of this research contains information appropriate to the factors involved in costing construction projects. The object of this study was to gain an understanding of the factors influencing contractors' cost estimating practice. This was achieved through a comparative study of eighty-four UK contractors classified into four categories, namely, very small, small, medium and large firms. The initial analysis of the 24 factors considered in the study shows that the main factors relevant to cost estimating practice are complexity of the project, scale and scope of construction, market conditions, method of construction, site constraints, client's financial position, buildability and location of the project. Analysis of variance, which tests the null hypothesis that the opinions of the four categories of companies are not significantly different, shows that except for the procurement route and contractual arrangement factor there is no difference of opinion, at the 5% significance level, on the factors influencing cost estimating. Further analysis, based on a factor analysis technique, shows that the variables could be grouped into seven factors; the most important factor grouping being project complexity followed by technological requirements, project information, project team requirement, contract requirement, project duration and, finally, market requirement.

Keywords: Cost estimate, factor analysis, tendering, cost estimators

Introduction

Cost estimating is crucial to construction contract tendering, providing a basis for establishing the likely cost of resource elements of the tender price for construction work. The impact of inaccurate cost estimating on contracting business is significant. Overestimated costs result in a high tender price being submitted by the contractor, which could lead to the tender being unacceptable to the client. On the other hand, an underestimated cost could lead to a situation where a contractor incurs losses on the contracts awarded by clients, and profitability in the construction industry generally is low compared with other industries (Akintoye and Skitmore, 1991). Thus, overestimated or underestimated cost has the potential to cause lost strategic opportunities to a construction contractor. The importance of a cost estimate is emphasized by Hicks (1992, p. 545) that 'Without an accurate cost estimate, nothing short of an act of god can be done to prevent a loss, regardless of management competence, financial strength of the contractor, or know how.' Smith (1995) considers that the process of cost estimating is very important as it enables construction companies to determine what their direct costs will be, and to provide a 'bottom line' cost below which it would not be economical for them to carry out the work.

Cost estimating can be described as the technical process or function undertaken to assess and predict the total cost of executing an item(s) of work in a given time using all available project information and

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resources (Kwakye, 1994). *The Code of Estimating Practice* produced by the Chartered Institute of Building (CIOB, 1997, p. xiii) defines estimating as 'the technical process of predicting costs of construction' and tendering as 'a separate and subsequent commercial function based upon the estimate'. Green (1989) compared estimating and tendering using systems concepts, estimating being classified as a closed system and tendering as an open system. Estimating takes place in a relatively sheltered environment and tendering in a changing and dynamic environment (Green, 1989).

On the other hand, a tender sum combines a cost estimate and mark-up, where mark-up comprises an allowance for general overhead recovery, profit etc. The mark-up is established at a level perceived by the contractor that the tender could be won at a margin that is in line with the strategic position of the firm within the market. Factors influencing the level of mark-up applied to tenders have been the subject of wide research (Eastham, 1986; King and Mercer, 1990; Sey and Dikbas, 1990; Shash, 1993). However, an important element of the tendering process, namely that dealing with factors influencing the cost estimating process, has not received much attention. This is in spite of empirical work by Azzaro *et al.* (1987) suggesting that cost estimates continue to provide the basis for most contractors' tender submission. Betts (1990) reports that tenders are based on a detailed analysis of the project and a detailed costing of those parts of the work to be done. Ashworth and Skitmore (1983) and Smith (1995), contrary to the CIOB (1997) definition of estimating as a technical function, argue that estimating cannot be a precise technical and analytical process but is, to a large extent, a subjective process. This argument by Ashworth and Skitmore (1983) and Smith (1995) tends to suggest that estimators consider factors relevant to the successful execution of a project. This is apart from variable items such as production rates, material wastage, etc., or other historical cost data derived from the company's files.

This paper documents and discusses factors considered by construction contractors' estimators when estimating for construction work, based on aggregated and disaggregated analyses of data collected in a survey of UK contractors ranging from very small to large size firms.

Overview of cost estimating practice and factors

Tender documentation used in the preparation of cost estimates includes drawings, specifications, conditions of contract, and bills of quantities. In collaboration with other departments within the company, the estimating department undertakes various tasks to arrive at the consolidated net cost estimate for the project. These tasks and the departments within the construction firm responsible for input towards estimating functions are documented in the *Code of Estimating Practice* (CIOB, 1997). The estimating department while preparing the cost estimate takes an overall view of the project and considers factors that may have an impact on pricing for the project, including production performance anticipated during the construction stage. The estimating department considers the resource required for the project in terms of quantity, quality, cost and performance, and other factors (such as the extent of information requirements, project environment, etc.) which may affect the performance of those resources to determine the consolidated cost estimate. The estimate of net cost is then presented to the senior management for addition of mark-up and subsequent adjudication in order to present a tender to the client.

Azzaro *et al.*'s (1987) empirical study commissioned by the Royal Institution of Chartered Surveyors investigated cost estimating from the viewpoint of the quantity surveyor working in the contracting sector. The study, based on a semi-structured survey of 11 main contractors and 2 subcontractors, sought to identify current estimating techniques and the types of data base used to arrive at tender prices. Issues covered in the study included the determination of unit prices, preliminaries items, and allowances for profits and overhead, as well as the adjustment of prices to take account of such factors as market conditions, site conditions, location and the nature of the tender documentation. The study failed to investigate the factors considered by estimators as part of construction contractors' estimating practice.

Tah *et al.* (1994), based on semi-structured interviews with seven contractors, investigated current practices of estimating the indirect costs (indirect costs were described as those which are not traceable to a specific work item, and consist of site overheads, general overheads, profits and allowances for risks) involved in tendering for construction work. The study, while recognizing the limitation of the research due to the low rates of response because of the sensitivity and confidential nature of the subject, concluded by indicating a high degree of subjectivity involved in indirect cost estimating. It also recognized that the percentage added to the cost estimate is based on the subjective judgement of senior management. The study reported that the subjective decision making processes involved in these tasks are characterized by qualitative data and knowledge that is often vague and difficult to structure and quantify. However, no investigation was undertaken to identify factors that are considered by estimators in arriving at decisions on cost estimates.

Skitmore and Wilcock (1994) investigated estimating processes of smaller builders based on an experiment conducted with eight practising builders' estimators. The work investigated the processes of estimating rather than the practice of cost estimating, by looking at methods that estimators used to price selected items from bills of quantities and the variability associated with the outcomes. The motivation for this investigation was that little descriptive material is available concerning the processes employed by builders in determining a tender price. The research concluded that the main factor determining the rating method (i.e., method of preparing unit rates for bills of quantities items) was the item quantity, although this varied in importance between the work sections investigated (groundwork, *in situ* concrete and masonry). An important conclusion emanating from the research was that not enough is known about factors involved in cost estimating in practice, although there is a wealth of prescriptive literature available on the subject.

The *Code of Estimating Practice* (CIOB, 1997) prescribes that the estimator, in the course of preparing a cost estimate, should carry out tasks such as a thorough examination of the tender documents, a site visit, the preparation of methods statement and tender programme, a visit to the project consultants, and make enquiries and receive quotations for materials, plant and subcontractors. These tasks are required to determine an approach to pricing the project at a level at which the costs of construction resources could be recovered. The *Code of Estimating Practice* also requests that the estimator should look for various factors, which may influence the approach to pricing, such as:

1. standard and completeness of the drawn information;
2. tolerances required;
3. clarity of the specification requirements and the quality required;
4. buildability;
5. whether load bearing and non-load bearing areas can be identified;
6. the extent of the use of standard details indicating previous construction experience;
7. evidence of design coordination of services and structural needs; and
8. the amount of information concerning ground conditions and foundations; and problem areas and restraints on construction in the design.

The advice provided in the *Code of Estimating Practice* on the factors that the estimator should look for appears inexhaustible. On the other hand, Akintoye and Skitmore (1992) have produced a conceptual model for construction contract pricing which suggests that the construction pricing process should include factors that influence cost estimating practice and data input to cost estimate.

Methodology

To obtain information on the factors considered by construction contractors in cost estimating practice, a postal survey of 200 randomly selected firms was undertaken, and 84 firms returned completed questionnaires in a usable format. The response rate of 42% was considered high compared with the norm of 20–30% with most postal questionnaire surveys of the construction industry.

Although the questionnaire survey dealt with various issues relating to current cost estimating practices in the UK, this paper documents only analyses of factors influencing the cost estimating element of the broader survey. The entire questionnaire extended to six pages. In the preparation of the questionnaire, a review of cost estimating literature was undertaken. In addition, the Akintoye and Skitmore (1992) paper on a conceptual model on 'pricing approaches in the construction industry' formed another basis for the empirical study.

A list of factors derived from the literature as potentially influencing cost estimating was identified for the contractors to provide opinion on the extent of influence of each factor on a five-point Likert-type scale. There were 24 factors listed in the questionnaire which, together with a covering letter was addressed to the managing director of the firm. The letter indicated the objectives of the research and requested that the questionnaire be completed by a senior staff member responsible for cost estimating activities in the firm.

For the analysis presented in this paper, the firms involved in the survey have been classified into four groups based on the turnover of the firm, as a measure of size grouping. Watt (1980) clarifies that the size of a company can be measured in terms of the number of employees, the net assets (capital employed), the value added (net output) and the turnover. Table 1 shows the grouping of the firms and the number of firms in each group. Tables 2 and 3 show the designation and the construction experience of the respondents, respectively. The respondents are mainly at the senior management level, with an average construction experience of about 28 years (standard deviation = 8.6).

Table 4 depicts the workload of the firms involved in the survey. The workload of the majority of the very small firms (95%) and small firms is building work, compared with medium and large companies with the

Table 1 Turnover of firms in the last financial year

Grouping	Turnover (£ million)	Number	Percentage
Very small	Less than 5	25	29.8
Small	5–25	26	31.0
Medium	25–100	16	19.0
Large	Over 100	17	20.2
Total		84	100

Mean = £69.55 million (standard deviation = 13.67)

Table 2 Designation of the respondents

Position[a]	Overall	Very small	Small	Medium	Large
Director–managing	15	7	7	1	
Directors	34	11	7	8	8
Senior managers	12	2	6	1	3
Managers	23	5	6	6	6
Total	84	25	26	16	17

[a]Directors include commercial, estimating, finance, regional, pre-contract; senior managers include chief and senior estimators, chief surveyors, head of building economics, etc.; managers include estimating managers, estimators, quantity surveyors, etc.

Table 3 Construction experience of the respondents[a]

Years	Overall	Very small	Small	Medium	Large
1–10	5	3	1	1	
11–20	13	3	6	3	1
21–30	36	10	11	9	6
Over 30	29	8	8	3	10
Not indicated	1				
Mean	27.5	26.1	27.0	25.7	31.9
Standard deviation	8.60	11.0	8.6	6.8	5.5

[a] F statistic = 1.999, $p = 0.121$.

Table 4 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

same significant proportion of civil engineering 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 relevant to civil engineering works.

Data analysis and results

Two separate statistical analyses were undertaken using the Statistical Package for Social Sciences (SPSS). The first analysis ranked the factors based on mean value of response, compared the mean for the groups and provided an analysis of variance (ANOVA), which tests the null hypothesis that the mean of the dependent variable (individual factor) is equal in all the groups.

The second analysis was intended to explore and detect underlying relationships among the cost estimating factors using factor analysis. Factor analysis is a statistical technique used to identify a relatively small number of factors that can be used to represent relationships among sets of many interrelated variables (Norusis, 1992). The principal component analysis for factor extraction is used in the analysis, the distinctive characteristic being its data-reduction capacity.

Analysis and ranking of cost estimating factors

As part of the analysis, the Cronbach alpha reliability is produced. Cronbach alpha reliability (the scale of coefficient) measures or tests the reliability of the five-point Likert-type scale used for the study (Norusis, 1992). The Cronbach's coefficient alpha is 0.897 (F statistic = 18.006, $p = 0.000$), indicating that the 5-point Likert scale used for measuring factors influencing cost estimating is reliable at the 5% significant level.

An analysis of the sample results, shown in Table 5, suggests that the main factors influencing cost estimating practice are complexity of the project, scale and scope of construction, market condition, method of construction, site constraints, client's financial position, buildability and location of the project. Most of these factors directly affect the performance (output of operatives) on site. Production performance data for labour, plant and subcontractor are required in the preparation of a cost estimate. Use of inappropriate production performance data in the determination of a cost estimate has a direct influence on the accuracy of the cost estimate, tender price, probability of winning a tender and profitability of the project during construction. It is not surprising, therefore, that these factors ranked highest as influencing factors in cost estimating practice.

With the exception of the client's financial situation, type of client, project team's experience of the construction type, and form of procurement variables that are significant at 5% level, there is no statistically significant difference in the opinion of the firms grouping of the other variables. This suggests that construction firms, irrespective of company size, generally have

Table 5 Factors influencing cost estimating

Factors		Overall	Rank	Very small	Rank	Small	Rank	Medium	Rank	Large	Rank	*F* Stat	Prob.
Complexity of design and construction	COMPLEX	4.464	1	4.520	1	4.269	1	4.563	1	4.588	1	0.955	0.418
Scale and scope of construction	SCOPE	4.179	2	4.120	4	4.115	2	4.500	2	4.059	5	1.108	0.351
Method of construction/ construction techniques	TECHNIQ	4.060	3	4.120	5	3.731	7	4.375	3	4.177	2	2.102	0.107
Tender period and market condition	MKTCOND	4.036	4	3.960	9	3.885	5	4.313	5	4.118	3	0.854	0.468
Site constraint – access and storage limitation	SITELMT	3.964	5	4.000	7	3.923	4	4.000	9	3.941	7	0.036	0.991
Clients financial situation and budget	FINANCE	3.927	6	4.320	2	3.654	10	4.250	7	3.471	14	2.656	0.054
Type of client	CLIENT	3.917	7	4.200	3	3.654	11	4.375	4	3.471	15	3.353	0.023
Buildability (including off-site prefabrication)	BUILDAB	3.821	8	3.640	13	3.731	8	3.938	10	4.118	4	1.022	0.387
Location of project	LOCATN	3.798	9	4.000	8	3.731	9	3.750	13	3.647	12	0.718	0.544
Availability and supplies of labour and materials	RESOURCE	3.774	10	3.560	14	3.808	6	3.875	11	3.471	16	0.663	0.577
Extent of completion of pre-contract design	DESIGN	3.762	11	3.800	11	3.385	14	4.188	8	3.882	9	2.468	0.068
Type of structure	STRUCTYP	3.760	12	3.269	19	4.000	3	3.647	17	2.176	24	2.176	0.097
Project team's experience of the construction type	PROJTEAM	3.726	13	4.040	6	3.346	15	3.875	12	3.706	11	2.367	0.047
Capability of the firm's construction team	FIRMTEAM	3.643	14	3.960	10	3.269	18	3.750	14	3.647	13	1.672	0.180
Quality of information and flow requirements	INFOQLTY	3.607	15	3.720	12	3.308	17	3.750	15	3.765	10	1.183	0.322
Project duration	DURATN	3.571	16	3.440	15	3.346	16	3.625	18	4.058	6	1.836	0.147
Lead times for delivery of materials.	LEADTIME	3.441	17	3.320	20	3.462	12	3.625	19	3.412	17	0.304	0.822
Form of procurement and contractual arrangement	PROCUREM	3.438	18	3.160	22	3.120	21	4.313	6	3.941	8	5.524	0.002
Expected project organization	PROJORG	3.417	19	3.440	16	3.269	19	3.750	16	3.294	20	1.027	0.385
Amount of special work / likely production time	SPECIWK	3.349	20	3.280	17	3.423	13	3.467	22	3.235	22	0.259	0.855
Off/on-site operations sequencing and limitations	SEQUENC	3.250	21	3.040	23	3.192	20	3.563	21	3.353	18	0.922	0.434
Anticipated frequency of construction variations	VARIATN	3.214	22	3.280	18	3.000	22	3.311	23	3.353	19	0.515	0.673
Expertise of consultants	CONSULTA	3.202	23	3.200	21	2.885	23	3.625	20	3.294	21	1.976	0.124
Number of project team members	NUMBTEAM	2.857	24	2.880	24	2.654	24	3.125	24	2.882	23	0.696	0.557

similar opinions regarding the factors influencing cost estimating practice.

The form of procurement and contractual arrangement was ranked 18th overall, but this is a major factor for the medium and large firms with a rank of 6 and 8, respectively. In recent years, different procurement methods have been used for large projects and it is likely that the medium and large size firms have noticed some cost implications associated with this variable. Most small projects still use the traditional procurement method based on either the JCT minor works or JCT 80 conditions of contract with or without quantities. Since there is nothing with which to compare the cost associated with this procurement method, it is not unexpected that very small firms (ranked 22) and small firms (ranked 21) have attached less importance to this factor.

Buildability was ranked in 10th position by the medium firms compared with a rank of 4 by large firms. The factor is ranked fairly high by the large firms; probably this explains why these firms are fairly well organized with adequate expertise in house to provide technical solutions to construction problems, whereas medium firms may not have the expertise in a reasonable amount to solve construction and buildability problems. In essence, more effort is required by medium firms to achieve buildability compared with large firms.

Overall, the analysis suggests that cost estimating practice focuses more attention on expected production performance of operatives on site and the impact of such factors as project complexity and integration.

Factor analysis of cost estimating factors

To capture any multivariate relationship existing between the cost estimating factors, the factor analysis technique was used to investigate the cluster of the relationship. This technique is appropriate (Hair *et al.*, 1995) because of little *a priori* knowledge about the number of different cluster relationships to expect, and as the members of these different tendencies were unknown.

Various tests are required for the appropriateness of the factor analysis for the factor extraction, including the Kaiser–Meyer–Olkin (KMO) measure of sampling accuracy, anti-image correlation, measure of sampling activities (MSA) and Barlett test of sphericity. The results of these tests are shown in the Appendix.

The 24 factors were subjected to factor analysis, with principal component analysis and varimax rotation. The first stage of the analysis is to determine the strength of the relationship among the variables, based either on correlation coefficients or partial correlation coefficients of the variables. The Appendix shows the partial correlation coefficients (same as the matrix of anti-image correlation) between the variables. The results of the partial correlation matrix show that the variables share common factors, as the partial correlation coefficients between pairs of the variables are small when the effect of the other variables is eliminated. According to Norusis (1992), the partial correlations should be close to zero when factor analysis assumptions are met, and if the proportion of large coefficients is high, then the use of the factor model should be reconsidered. The Appendix also displays the MSA on the diagonal of the matrix. The value of the MSA must be reasonably high for a good factor analysis. In this case, the value of the MSA was 0.6085–0.8516, suggesting no need to eliminate any variable from the analysis.

Barlett's test of spericity tests the hypothesis that the correlation matrix is an identity matrix. In this case, the value of the test statistic for spericity is large (Barlett test of sphericity = 977.239) and the associated significance level is small ($p = 0.000$), suggesting that the population correlation matrix is not an identity matrix. Observation of the correlation matrix of the cost estimating factors shows that they all have significant correlation at the 5% level, suggesting no need to eliminate any of the variables for the principal component analysis. The value of the KMO statistic is 0.748, which according to Kaiser (1974) is satisfactory for factor analysis. In essence, these tests show that factor analysis is appropriate for the factor extraction.

Principal component analysis was undertaken which produced a seven-factor solution with eigenvalues greater than 1, explaining 70.4% of the variance. Then varimax orthogonal rotation of principal component analysis was used to interpret these factors. An unrotated principal component analysis factor matrix indicates only the relationship between individual factors and the variables, and sometimes it is difficult to interpret the pattern. Rotation techniques, such as the varimax method, transform the factor matrix produced from an unrotated principal component matrix into one that is easier to interpret. The factor grouping based on varimax rotation is shown in Table 6. Each of the variables weighs heavily on to only one of the factors, and the loading on each factor exceeds 0.5. The factors and associated variables, which are shown in Table 7, are readily interpretable as follows: factor 1 represents project complexity; factor 2 is technological requirement; factor 3 is project information; factor 4 represents project team requirement; factor 5 represents contractual arrangement; factor 6 is project duration; and factor 7 is market requirement.

Table 6 Rotated factor matrix (loading)

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
STRUCTYP	0.7307						
SCOPE	0.6990						
PROJORG	0.6965						
COMPLEX	0.6854						
SITELMT	0.6736						
TECHNIQ	0.6330						
SPECIWK		0.8726					
LEADTIME		0.8431					
SEQUENC		0.7859					
BUILDAB		0.5000					
INFOQLTY			0.7295				
RESOURCE			0.7031				
DESIGN			0.6833				
CONSULTA			0.6026				
FIRMTEAM				0.8367			
PROJTEAM				0.7916			
NUMBTEAM				0.6925			
CLIENT					0.8722		
FINANCE					0.7093		
PROCUREM					0.5804		
DURATN						0.7463	
VARIATN						0.6997	
LOCATN							0.7403
MKTCOND							0.5689
Eigenvalue	6.991	2.995	1.972	1.442	1.284	1.181	1.029
Percentage of variance	29.1	12.5	8.2	6.0	5.4	4.9	4.3

Discussion of factor analysis results

Project complexity

Project complexity factor grouping is made up of type of structure, scale and scope of construction, complexity of design, site constraints and expected project organization. It is noteworthy that these variables are loaded together under the same factor. Project scope is a definition of the client's requirements for space, building function, and quality of the proposed project. Handy (1985) regards size (scope and scale of construction) as a single variable in determining the appropriate construction team organizational structure (expected project organization). Woodward (1980) demonstrated that the technology of production (method of construction) is an important variable in determining the appropriate organization for successful firms. Bennett and Fine's (1980) research showed that project complexity can be viewed in terms of size of a task, speed of production, extent of repetition, number of operations, incidence of different kinds of work and extent of predictability of operations. Gidado and Millar (1992) regarded complexity as factors that hinder performance on site, including technical complexity of the task, amount of overlap and interdependencies in construction stages, project organization, site layout, and unpredictability of work on site. It is considered that project complexity affects contract duration and consequently the construction cost. The study by Bennett and Fine concluded that the size of a task (e.g. by repeating the same sequence of operations and extent of degree of interference with construction – measures of project complexity – with consequent effect on project organizational structure) affects project work breakdown unit costs and duration.

The standard method of measurement, which forms the basis for the measurement of item quantities provided in bills of quantities, recognizes the type of work (including type of structure) as a measure of complexity. However, estimators like to consider other factors to decide upon the complexity of a construction project, as shown by the variables included in the factor grouping. These variables have direct consequences for the production performance on site and effectively the profitability of a particular project.

Table 7 Factor analysis grouping using varimax orthogonal rotation

Influencing factors	Principal components						
	Factor 1 Project complexity	Factor 2 Technological requirements	Factor 3 Project information	Factor 4 Project team requirement	Factor 5 Contract requirements	Factor 6 Project duration	Factor 7 Market requirement
1	Expected project organization	Amount of specialist work	Quality of information and information flow	Capacity of design team	Type of client	Project duration	Location of project
2	Type of structure	Lead time (delivery and circumstances)	Availability and supplies of resources (labour & materials)	Project team experience on the type of construction	Client's financial standing	Anticipated frequency or extent of variations in construction requirements	Tender period and market condition
3	Site constraints (e.g. access and storage limitations)	Off/on-site operations sequence and limitations	Pre-contract design (extent of design/ construction interface)	Number of project team members	Procurement route and contractual arrangement		
4	Method of construction and construction technique	Buildability	Expertise of the consultants involved in the project				
5	Scale and scope of construction						
6	Complexity of design and construction						

Technological requirements

Technology factor grouping is made up of the amount of specialist work, lead time for delivery of materials, proportion of off-site and on-site operations, sequence and limitations of operations and buildability. Innovation in construction technology and processes brings all the elements together. These elements are also related to subcontract operations. In recent times, the amount of subcontracting in construction procurement has increased. Specialist works are most likely to be undertaken by subcontractors, in addition to work that requires off-site production such as steel and concrete prefabrication. Long lead time materials are most likely to be supplied by nominated construction suppliers. The integration of services into the construction process and the extent of prefabrication would have an impact on the buildability of a project (More, 1996).

Cost estimators would invariably consider these elements carefully as they impact on the profitability and management of a project, particularly where the work is undertaken substantially by the main contractor's domestic or approved subcontractors. Smith (1995) regards subcontract work as a factor of production (an input to the project) just like labour, material and plant, for which an estimator will need to determine its total cost. Moreover, Smith (1995, p. 81) has argued that 'whatever the circumstances of any particular project it is likely that a substantial proportion of the work, almost certainly in excess of 50%, will be carried out by subcontractors of one kind or another, and it is therefore essential for estimators to have a detailed knowledge of the factors that govern the incorporation of subcontractors' prices into the main contractor's estimate'. Consequently, the estimating practice adopted on a project will depend on the balance between the amount of work to be undertaken by the main contractor and its subcontractors and the amount of materials and equipment to be supplied by the company suppliers or nominated suppliers. The quantity of subcontracting work and suppliers involved probably will depend on the technology and innovation required in the work. Since the technological requirement of a project determines the amount of subcontract work required, it is to be expected that these factors have been weighted highly.

Project information

CIOB (1997) requires that, for the preparation of a pre-tender construction programme, estimate and tender, the construction firm should gather enough project information for these functions to be performed effectively and efficiently. Some of this information includes basic information on the client, project details, drawings (including site layout, specifications, schedules, technical reports and bills of quantities). The essence of this information requirement is to establish the type of work and the resources required.

The project information factor grouping comprises the quality of information and information flow, availability and supply of resources, extent of pre-contract design completion, and the expertise of the consultants involved. Since the consultants supply most of the information required for the estimating function, the expertise available within the consultant organizations may have a bearing on the amount of detailed design available during tender stage, the quality of information provided and the efficiency of flow of such information.

Project team requirement

It is the estimating department's responsibility, with input from the contract department, to establish the resources (e.g. finance, staff and labour) required for a project, bearing in mind the particular skills quality needed for a project, plus the availability of material and plant (CIOB, 1997). The supervision of site work is important as this determines the level of efficiency achieved on a construction site and, consequently, the profitability of the project.

The supervisory team available within the company, in terms of quality and quantity, must match the project type and quality expectation. It must be decided, as part of the estimating function, whether the appropriate supervisors are available. This decision may involve not only identification or recruitment of new supervisory resources for the project but also the re-organization of the existing labour resources. The decision taken in this respect must be considered within the overall corporate business strategy of the firm. Considering this, it is to be expected that the capacity of the project team within the company, project team experience on the type of construction and number of project team members have been placed in fourth position.

Contractual arrangement

Information on the type of client is important as part of the project assessment and appraisal processes. The type of client, client's financial standing and procurement route and contractual arrangement have been grouped in fifth position under a factor heading of 'contractual arrangement'. It is predictable that these have not been weighed highly because the company must have considered these issues very carefully as part of the decision to tender process and before committing to submit a tender for the project. If this decision has been considered as part of the decision to tender process and the company is satisfied with the type of client, client's financial position and the conditions under which the project will be let, then these issues become less significant in the estimating function.

Project duration

Factor grouping for project duration includes the anticipated frequency and extent of variations to the client's building requirements. The extent of variations has a potential impact on the completion time for a project. Apart from these factors having an impact on the resources required for the project, they affect the pricing of preliminaries (including site overheads) and general overheads. In the study undertaken by Azzaro *et al.* (1987), the contractors involved in the research considered that preliminaries, particularly time related items (i.e. project duration), were the areas which won or lost them contracts, and which resulted either in a profit or loss on the contracts they won.

Normally the contract planning department is responsible for calculating the duration for the entire project and the resources required, while the estimating department is responsible for pricing resource requirements as assessed by the planners. Since the duration of a project is an input from another department, although this is very important in cost estimating for a project, it is to be expected that this factor has been placed in sixth position.

Market requirements

This factor grouping comprises the location of the project, tender period and market condition. The cost estimator in the estimating process must take into account the trends in market conditions and the implications on the costs of the resources for the project. The location of the project is important. According to Cleveland (1995), remoteness of site must be analysed completely for cost elements that are unique to the location and have the greatest effect on the cost estimate. Since these factors are considered also in the subsequent function of mark-up determination and tendering process (Eastham, 1986; Sey and Dikbas, 1990), it is not unexpected that the factor grouping ranked seventh.

Conclusion

The focal point of this analysis was the factors considered by construction companies in cost estimating practice. An exploration of these factors was conducted through an interrelationship between variables using the factor analysis technique.

Although the literature on cost estimating tends to suggest the principle involved in cost estimating is a technical process, a general view is that cost estimators take into account some factors that form the basis for their costing. This being the case, the implication could be that more research effort should be concentrated into the cognitive issues involved in project costing by the estimators rather than looking into estimating principles. This view was presented by Carr (1989), who argued that the current estimating practices and associated literature give little attention to establishing a fundamental base or foundation to estimating decisions, so that the formats, procedures and processes will provide estimates that are accurate and useful for decisions making.

There is a general view in the industry that the accuracy of cost estimates is crucial to all parties involved with the construction project. As a result, an analysis of the factors involved in cost estimating becomes imperative. An initial analysis of the factors shows that the main factors relevant to the cost estimating practice are complexity of the project, scale and scope of construction, market condition, method of construction, site constraints, client's financial position, buildability and location of the project. It is believed that these factors have a direct effect on productivity levels on site and performance of the construction project. Except for procurement route and contractual arrangement there is no difference of opinion, at the 5% significance level, on the factors influencing cost estimating on a company size basis.

Further, using the factor analysis technique based on the same data shows the 24 variables considered in the study could be grouped into 7 factors with the most important being project complexity followed by technological requirements, project information, project team requirement, contract requirement, project duration and finally market requirement. It is recognized therefore that these factor groupings, representing the elements considered in cost estimating practice, should be considered by construction contractors in their cost estimating decisions.

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Appendix

Anti-image correlation matrix[a]

	BUILDAB	CLIENT	COMPLEX	CONSULTA	DESIGN	DURATN	FINANCE
BUILDAB	0.80587						
CLIENT	0.00843	0.64380					
COMPLEX	−0.17162	0.06441	0.67941				
CONSULTA	−0.00660	−0.25095	0.03426	0.88036			
DESIGN	−0.00855	−0.39494	0.08811	−0.11727	0.80763		
DURATN	0.21146	0.29595	−0.25331	−0.12684	−0.23312	0.66421	
FINANCE	0.12398	−0.54521	0.12549	0.14850	0.16360	−0.08369	0.71333
FIRMTEAM	−0.00245	0.00804	0.01376	0.01006	0.05468	−0.00926	0.08048
INFOQLTY	0.06400	0.31363	−0.14862	−0.00484	−0.49401	0.17745	−0.27212
LEADTME	−0.07371	−0.01751	−0.19338	−0.04801	0.13163	0.05945	−0.14957
LOCATN	0.06102	0.03894	0.17675	−0.17533	0.12253	0.01161	−0.06207
MKTCOND	−0.09804	−0.03225	0.08829	−0.11705	−0.00785	−0.19728	−0.07635
NUMBTEAM	−0.12367	0.19272	0.21742	−0.00351	−0.10091	0.04895	−0.08452
PROCUREM	−0.20271	−0.40454	0.00988	0.14589	0.03720	−0.19152	0.13181
PROJORG	−0.00357	−0.06585	−0.03566	−0.05558	0.09898	0.00570	−0.09348
PROJTEAM	−0.00573	0.00038	−0.10233	−0.27919	−0.13994	0.03901	−0.20026
RESOURCE	−0.11611	0.00785	0.27503	−0.36631	0.03846	−0.29746	0.00247
SCOPE	0.04639	0.02084	−0.49502	−0.07614	−0.14719	0.13022	−0.12494
SEQUENC	0.16148	−0.09562	−0.05203	−0.06303	0.00657	0.19534	0.23186
SITELMT	0.13740	0.02543	−0.14278	−0.03244	−0.01186	0.20691	0.09567
SPECIWK	−0.17483	0.07031	0.10922	0.17776	−0.12191	−0.17356	−0.11973
STRUCTYP	−0.00360	−0.09783	−0.24905	−0.02829	0.05279	−0.10300	0.01474
TECHNIQ	−0.42051	0.19072	−0.05627	−0.04540	−0.07904	−0.06978	−0.09313
VARIATN	−0.33384	−0.13314	0.10981	−0.13596	0.09326	−0.45620	−0.12267

	FIRMTEAM	INFOQLTY	LEADTME	LOCATN	MKTCOND	NUMBTEAM	PROCUREM
FIRMTEAM	0.70651						
INFOQLTY	0.20109	0.66835					
LEADTME	–0.24342	–0.15910	0.75935				
LOCATN	–0.09791	–0.24105	–0.10934	0.60854			
MKTCOND	0.07859	–0.05599	–0.21398	–0.12059	0.83606		
NUMBTEAM	–0.20746	0.06257	0.10111	0.06484	–0.16987	0.78464	
PROCUREM	0.17710	–0.15882	–0.16668	0.05212	0.14208	–0.27013	0.75060
PROJORG	–0.22692	–0.05725	0.15584	0.12464	0.15931	–0.00762	–0.16031
PROJTEAM	–0.60151	–0.23235	0.06097	0.16495	0.00608	–0.16976	0.02697
RESOURCE	–0.30689	–0.35366	–0.06306	0.32476	0.01365	0.04560	–0.06478
SCOPE	–0.04327	0.26411	–0.08281	–0.18028	0.04206	–0.07914	–0.06774
SEQUENC	–0.08647	–0.06847	–0.07485	–0.05276	0.03058	0.20262	–0.27656
SITELMT	0.11902	–0.06933	0.17916	–0.08450	–0.24138	–0.11662	0.04527
SPECIWK	0.25372	0.28724	–0.54265	–0.07926	0.13630	–0.15628	0.23539
STRUCTYP	0.11797	0.18678	0.23004	–0.37383	–0.10127	–0.15863	0.01942
TECHNIQ	–0.14068	–0.08217	0.07045	–0.05533	–0.02902	0.10114	–0.04356
VARIATN	–0.09663	–0.19261	0.09868	0.07194	0.00949	–0.10201	–0.00653

	PROJORG	PROJTEAM	RESOURCE	SCOPE	SEQUENC	SITELMT	SPECIWK
PROJORG	0.80905						
PROJTEAM	0.09219	0.73194					
RESOURCE	0.01950	0.34415	0.69981				
SCOPE	0.00935	0.13469	–0.09426	0.74351			
SEQUENC	0.19124	0.00439	–0.08960	0.10754	0.77094		
SITELMT	–0.25231	–0.04985	–0.18150	–0.21898	–0.10622	0.81060	
SPECIWK	–0.15934	–0.15577	–0.16856	0.02424	–0.48947	–0.09727	0.68858
STRUCTYP	–0.29804	–0.13480	–0.17532	0.00528	–0.10567	0.07642	0.01162
TECHNIQ	–0.17102	0.13779	0.13551	–0.02061	–0.15050	–0.16208	–0.11516
VARIATN	–0.07326	0.12631	0.35766	–0.14415	–0.25520	–0.01200	0.10983

	STRUCTYP	TECHNIQ	VARIATN
STRUCTYP	0.77965		
TECHNIQ	–0.14618	0.85161	
VARIATN	0.08636	0.14864	0.66725

[a] Measures of sampling adequency (MSA) are printed on the diagonal; Kaiser–Meyer–Olkin measure of sampling adequacy = 0.74807; Bartlett test of sphericity = 977.23947, significance, $p = 0.0000$.