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Evaluating contractor prequalification data: selection criteria and project success factors

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A Delphic study investigating the perceived relationship between 20 contractor selection criteria (CSC) currently in use and project success factors (PSFs) in terms of time, cost and quality is described involving a sample of eight experienced construction personnel, including two validators. A consensus of the likely impact of each criterion on time, cost and quality is established in terms of pessimistic, average and optimistic values, which are then converted into expected means and variances via the PERT approach. The ten most and ten least important CSCs are identified and examined for differences and similarities between PSFs. The results show that past failures, financial status, financial stability, credit ratings, experience, ability, management personnel and management knowledge are perceived to be the dominant CSCs affecting all three PSFs, with safety criteria (safety, experience modification rate, OSHA incidence rate, management safety accountability) and the length of time in business being perceived to have the least effect overall. Some CSCs, such as past performance, bank arrangements, project management organization, plant and equipment were perceived to affect only one or two PSFs.

Keywords: Prequalification, selection criteria, project success factors, Delphic study.

Introduction

One of the most difficult decisions taken by the client in the construction industry is selecting the contractor. Every construction project faces adversity and uncertainty, and an inappropriate contractor increases the chances of delays, cost overruns, substandard work, disputes, or even bankruptcy. One method of ensuring that a contractor is able to execute the assigned project in accordance with all client and project objectives is to assess the contractor's capabilities at a prequalification stage and tender evaluation stage.

Prequalification is a pre-tender process used to investigate and assess the capabilities of contractors to carry out a contract satisfactorily should it be awarded to them. The current practice of prequalification involves a screening procedure based on a set of criteria, and has been examined by several researchers (e.g. Hunt *et al.*, 1966; Helmer and Taylor, 1977; Russell and Skibniewski, 1987, 88; Merna and Smith, 1990; Ng, 1992; Holt *et al.*, 1994; Potter and Sanvido, 1994, Hatush, 1996). For prequalification to be useful, however, it is necessary to know how these different criteria are likely to affect the main project objectives in terms of time, cost and quality. The evidence to date suggests that such knowledge is lacking, with most client (and consultant) prequalifiers being more concerned with the process of retrieving completed proformae from candidate contractors than with undertaking any serious study of the relationships of this data to the project objectives (Hatush, 1996). Neither have these relationships received any attention from researchers in the field. This may be a result of the long-term confidence in the pre-selection process, and the fact that final selection is made predominantly on the cost elements of tenders (Holt, 1994). Another possible reason may be the lack of post-construction evaluation generally (Akatsuka, 1994), with Russell *et al.*, (1992) for instance suggesting that owners do not feel that prequalifying contractors is important

enough to warrant the expenditure involved. As a result, clients may be subjecting themselves to unnecessary risk of admitting contractors with inadequate ability, capacity, and experience to fulfil the required project objectives.

This paper presents the results of a Delphic study investigating the perceived relationship between 20 contractor selection criteria (CSC) currently in use and the predominant project success factors (PSFs) in terms of time, cost and quality, involving a sample of eight experienced construction personnel, including two validators. A consensus of the likely impact of each criterion on time, cost and quality is established in terms of pessimistic, average and optimistic values, which are then converted into expected means and variances via the PERT (program evaluation and review technique) approach. The ten most and ten least important CSCs are identified and examined for differences and similarities between PSFs.

The results show that past failures, financial status, financial stability, credit ratings, experience, ability, management personnel and management knowledge are perceived to be the most dominant CSCs affecting all three PSFs, with safety criteria (Safety, experience modification rate, OSHA incidence rate, Management safety accountability) and the length of time in business being perceived to have the least effect overall. Some CSCs, such as past performance, bank arrangements, project management organization, plant and equipment, were perceived to affect only one or two PSFs.

The major benefit of this study is to document the anticipated effect of the various CSCs on client objectives in terms of PSFs, and also in providing a basis for the future development of quantitative techniques for contractor selection.

Project success factors (PSFs)

All procurers have goals or concerns that can be described in similar terms. These all contribute in different degrees to the predominant project success factors of *time*, *cost* and *quality*.

Time

The time to complete the project is scheduled to enable the building to be used by a date determined by the client's future plans. Clients vary in their willingness to employ only those contractors who are able to meet target dates. Some contracts include a bonus clause to encourage the contractor to speed up the construction process and to avoid any delays.

Cost

Historically, cost is the factor considered to be most important by clients. Most seek value for money, although this is often taken to mean spending as little as possible. The traditional competitive tendering system is based on this premise. One result of this is that cost, measured by the bid price submitted by the contractor, is often regarded as the sole criterion for contractor selection. A large majority of projects, however, end up costing more than the original bid price (Hardy, 1978).

Quality

Quality in construction is defined as 'the totality of features required by a product or service to satisfy a given need' (BS 5750, 1987). It is thought that the implementation of new procurement systems has resulted in a decline in quality in recent years (Hindle and Rwelamila, 1993) and, for this reason alone, quality is regarded as a main criterion in contractor selection (Latham, 1994).

Research methodology

A questionnaire (see Appendix 1) was developed to enable information to be collected on each subject's perception of the extent to which each CSC affects the three PSFs of time, cost, and quality. Hatush's (1996) CSCs were used.

The questionnaire was designed to allow interviewees complete freedom to enter any value that reflected their opinion on the influence of the CSC, and not to restrict them to some arbitrary values provided by the researchers. There are two reasons for this: (1) there is no previously published work quantifying the effect of CSCs on PSFs; and (2) the researchers believed that letting the interviewees put any value that represented their own opinions would make the investigation more flexible to the interviewees. The difficulty of this technique, however, is in interpreting and finding some compromise among all these different values.

In order to make the interviewing more effective, and to save the time of the interviewees, the questionnaire, with a description of the purpose and needs of the research, was sent to the interviewees several days in advance of the interviews. In addition, the purpose of the interview was explained briefly through a telephone conversation. This was then reinforced and discussed further during the interview itself and included as part of the data collection exercise.

A select list of potential interviewees was compiled from different organizations and from personal

contacts of the researchers, and a sample of eight construction professionals with relevant construction industry experience were ultimately interviewed. The interviews were conducted at the interviewees' own offices, comprising three public client organizations and five private client organizations in the north west of England. Each interview ranged from 1 to 2 hours and was tape-recorded.

The interview procedure comprised three phases, as follows.

First phase

In the first phase six professionals were requested to describe the effect of each criterion on time, cost, and quality in terms of three values – pessimistic (P), average (A), optimistic (O) – depending on the contractor characteristic involved (e.g. financially stable or financially unstable). In question 1 (financial stability), for example, interviewees were requested to provide P, A and O values for financially stable contractors and also P, A and O values for financially unstable contractors in terms of the likely effect on project time, cost and quality. The same procedure was then applied for the whole list of questions.

All values were requested as percentages, where 100% is considered as the desired level to be achieved for time, cost, and quality: the lower the value for time and cost the better, while for quality the higher the better. For example, 108% for cost and time means an expectation of 8% overrun on scheduled cost and time, while 108% for quality means an expectation of 8% improvement in specified quality.

Once the data from the six interviewees had been collected, the *mean* P, A and O values were calculated for each criterion and for the three objectives for both types of contractor.

Second phase

The second phase of the procedure involved the same six interviewees again being visited. This time the interviewees were shown the *mean* values produced by the first phase along with their original estimated values. They were then given the opportunity to change their original values if they wished. This was carried out with each interviewee for all 20 CSCs and 18 elements of the questionnaire. The means of the revised values were then recalculated, as shown in Appendix 2.

Third phase

Interviews with another two experienced professionals were next conducted to validate the values thus far obtained and to check whether the revised means could be accepted as reasonable default values for possible use in any future system development. Each validator was provided with the mean values shown in Appendix 2 and requested to describe how much each criterion affected time, cost, and quality, and either to agree on the value given or modify if there was a significant change. The results of this phase were very encouraging, with one validator agreeing to all values without a single change, and the other validator making a very slight change in the safety criterion. This was taken to indicate that a reasonable consensus existed on the default status of the values given in Appendix 2.

Statistical analysis

The *expected mean* and *variance* values for the three PSFs for each decision criterion were determined and an analysis of their impact made. The 90, 95, and 99% confidence intervals for the expected means and standard deviation were calculated. The relationships between CSCs for each PSF were established from the linear correlation coefficients. Tests of hypotheses of the population correlation coefficient for the three PSFs were evaluated for different statistical significance. In the subsequent section, each analysis technique is described along with their results. A summary of these statistical analyses results is also highlighted.

Expected means and variance values

The expected means and variances of the time, cost and quality PSFs for each criterion and for each type of contractor were calculated from the P (pessimistic), A (average) and O (optimistic) values given in Appendix 2 by use of the PERT method (e.g. Horowitz, 1967; Harris, 1978; Loomba, 1978), assuming a beta distribution, as follows:

$$\text{Expected time, } E_t = \frac{P + 4A + O}{6} \tag{1}$$

$$\text{Expected cost, } E_c = \frac{P + 4A + O}{6} \tag{2}$$

$$\text{Expected quality, } E_q = \frac{P + 4A + O}{6} \tag{3}$$

$$S = \frac{\text{Highest value } P \text{ or } O - \text{Lowest } P \text{ or } O}{6} \tag{4}$$

in which P and O are the same as defined above. The variance is given by squaring σ.

For example, the three estimated values for the 'financial stability' criterion are, from Appendix 2:

	Financially unstable contractor			Financially stable contractor		
	P	*A*	*O*	*P*	*A*	*O*
Time	118	107	102	105	100	95
Cost	118	108	100	105	100	97
Quality	87	93	100	95	100	108

Using Equations 1–4 gives, for financially unstable contractors:

$$E_t = (118 + 4 \times 107 + 102)/6 = 108$$
$$S_t = (118 - 102)/6 = 2.67$$
$$V_t = (S_t)^2 = 7.12$$

$$E_c = (118 + 4 \times 108 + 100)/6 = 108$$
$$S_c = (118 - 100)/6 = 3.00$$
$$V_c = (S_c)^2 = 9.00$$

$$E_q = (87 + 4 \times 93 + 100)/6 = 93$$
$$S_q = (100 - 87)/6 = 2.17$$
$$V_q = (S_q)^2 = 4.70$$

and for financially stable contractors:

$$E_t = (105 + 4 \times 100 + 95)/6 = 100$$
$$S_t = (105 - 95)/6 = 1.67$$
$$V_t = (S_t)^2 = 2.78$$

$$E_c = (105 + 4 \times 100 + 97)/6 = 100$$
$$S_c = (105 - 97)/6 = 1.33$$
$$V_c = (S_c)^2 = 1.77$$

$$E_q = (95 + 4 \times 100 + 108)/6 = 100$$
$$S_q = (108 - 95)/6 = 2.17$$
$$V_q = (S_q)^2 = 4.70$$

The expected values, standard deviations and variances of all the CSC were calculated in this way, and the results are shown in Appendix 3.

Confidence intervals of expected and standard deviation values

The expected values and variance parameters for time, cost and quality calculated so far are for a sample of a population. These values were than used to estimate the range (confidence interval) within which the population might occur. 90%, 95% and 99% confidence interval estimates of the population expected values (μ) and population standard deviation (σ) for time, cost, and quality were calculated using small sample ($n < 30$) theory (e.g. Spiegel, 1980) Note that, in small sampling theory, the standard deviation of the sample is used instead of the population standard deviation (σ), as σ is invariably unknown. It is generally desirable that the width of a confidence interval be as small as possible.

Tables 1 and 2 show the 90% confidence intervals of μ along with the sample expected values (E), and σ along with the sample standard deviation (S), for the whole list of CSC.

Highest-rated CSC by expected values

The risk in most cases comes from selecting a contractor with undesirable characteristics (e.g. financially unstable, low credited, or inadequate plant). In this and the following sections, therefore, the data for contractors with such undesirable characteristics are used for analysis. For analysis and for the sake of clarity, the ten CSCs that have the largest and smallest effect are presented in Tables 3 and 4 for both undesirable and desirable characteristics.

Table 3 present the CSCs that had the highest expected effect, ranked in decreasing order for each of time, cost and quality. The highest common risk contractor selection criterion observed in all the three PSFs is the *past failures* of the contractor. Thus it can be concluded that this criterion is very important and should be applied when performing prequalification, or in the evaluation stage of tenders. *Financial status* is the second highest risk decision factor for all PSFs. Other risk decision criteria that are among the highest ten CSCs in all the PSFs are the *ability* of the contractor, *management personnel* and *experience*.

In further comparison of the three PSF groups it is interesting to note their commonalities. For example, *bank arrangements* is considered to be an important factor for time and cost. Although this criterion is not in the top ten for quality, it received 95% expected value, and it is viewed as a significant factor for quality. *Management knowledge*, *project management organization* and *past performance* are indicated as important risk decision criteria for time and quality, as they appear in the top ten list for each of these PSFs, receiving about 110% for time and 92% for quality. These same three CSCs scored only 107% for cost, and appear in the list of the lowest ten CSCs in Table 4. The *other relations* criterion is considered important for time and cost, and is the lowest in the quality list, indicating that the criterion is also considered important for quality. *Financial stability*, on the other hand, seems to have a moderate effect on cost and quality.

Credit ratings from subcontractors and suppliers and *owner/contractor relationships* are the only CSCs to appear in the top ten questionnaire items for cost. This result reflects the emphasis placed on these two CSCs on reducing the cost risk and in achieving the bid price

Table 1 90% confidence intervals of the expected values

Contractor selection criteria	Project success factors	Undesirable contractor			Desirable contractor		
		Maximum (μ)	E	Minimum (μ)	Maximum (μ)	E	Minimum (μ)
Financial stability	Time	110.02	108	105.25	101.51	100	98.49
	Cost	110.82	108	105.3	101.53	100	99.02
	Quality	90.77	93	94.79	98.55	100	102.56
Credit rating	Time	110.26	107	104.74	101.45	100	97.44
	Cost	112.97	110	107.25	101.17	100	98.06
	Quality	92.970	95	96.48	98.34	100	101.5
Bank arrangements	Time	113.60	111	108.18	100.95	100	97.94
	Cost	109.79	108	105.77	101.11	100	98.05
	Quality	93.480	95	96.24	99.27	100	101.28
Financial status	Time	115.48	112	108.80	101.69	100	97.98
	Cost	113.08	111	108.31	100.96	100	98.04
	Quality	87.97	90	91.48	98.75	100	101.25
Experience	Time	112.75	110	106.98	101.58	100	97.97
	Cost	112.22	110	106.95	101.34	100	98.38
	Quality	90.80	93	95.31	98.92	100	101.53
Plant and equipment	Time	111.41	109	106.64	101.51	100	98.49
	Cost	108.72	106	104.45	100.95	100	98.89
	Quality	95.20	97	97.96	99.68	100	101.04
Technical personnel	Time	110.08	109	106.31	101.06	100	97.94
	Cost	108.15	107	104.63	101.61	100	98.50
	Quality	89.61	91	92.72	98.92	100	101.53
Ability	Time	113.57	111	107.54	101.51	100	98.49
	Cost	111.11	108	105.84	101.25	100	98.75
	Quality	88.89	92	94.16	98.48	100	101.24
Past performance	Time	112.2	109	106.63	101.02	100	97.15
	Cost	108.95	107	104.88	101.35	100	98.49
	Quality	89.69	92	94.36	99.49	100	102.35
Project management organization	Time	112.77	110	107.50	102.00	100	97.83
	Cost	108.97	107	105.20	101.51	100	98.65
	Quality	89.55	92	93.67	98.92	100	101.53
Management personnel	Time	114.96	112	108.93	101.32	100	97.96
	Cost	109.68	108	105.76	101.60	100	98.34
	Quality	89.37	92	93.13	99.38	100	102.34
Management knowledge	Time	113.36	111	108.59	101.34	100	98.33
	Cost	107.83	106	103.56	101.50	100	98.39
	Quality	90.51	92	94.77	99.35	100	101.81
Safety performance	Time	103.62	103	101.66	100.64	100	99.19
	Cost	102.53	102	101.08	100.38	100	99.18
	Quality	100.23	100.17	100.43	99.86	100	100.31
Experience modification rate	Time	103.35	102	101.65	100.39	100	99.33
	Cost	103.35	102	101.65	100.39	100	99.33
	Quality	98.43	99	99.29	99.59	100	100.14
OSHA incidence rate	Time	104.34	103	102.33	100.31	100	98.91
	Cost	102.43	102	101.18	100.33	100	99.17
	Quality	100.00	100	100.00	100.00	100	100.05
Management safety accountability	Time	101.69	101.67	101.14	100.00	100	100.0
	Cost	101.69	101.67	101.14	100.00	100	100.0
	Quality	99.47	99.67	99.97	99.79	100	100.10
Past failures	Time	114.52	113	110.76	101.57	100	97.60
	Cost	116.98	114	111.46	101.51	100	98.49
	Quality	86.88	89	90.90	98.77	100	101.78
Length of time in business	Time	102.10	101	99.84	100.85	100	99.15
	Cost	102.36	102	100.86	101.65	100	99.19
	Quality	94.36	96	96.87	98.90	100	101.10
Owner/contractor relationship	Time	106.51	105	103.49	101.06	100	98.10
	Cost	109.47	107	104.70	101.53	100	98.92
	Quality	93.79	96	97.05	99.42	100	101.13
Other relations	Time	111.74	110	107.98	100.95	100	97.94
	Cost	110.06	108	106.05	101.53	100	99.02
	Quality	91.55	93	94.56	99.01	100	101.27

Table 2 90% confidence intervals of standard deviation values

Contractor selection criteria	Project success factors	Undesirable contractor			Desirable contractor		
		Maximum (σ)	*S*	Minimum (σ)	Maximum (σ)	*S*	Minimum (σ)
Financial stability	Time	6.04	2.67	1.94	3.82	1.67	1.23
	Cost	6.99	3.00	2.25	3.18	1.33	1.02
	Quality	5.09	2.17	1.63	5.09	2.17	1.63
Credit rating	Time	6.99	3.00	2.25	5.09	2.17	1.63
	Cost	7.25	3.17	2.33	3.94	1.67	1.27
	Quality	4.45	2.00	1.43	4.01	1.67	1.29
Bank arrangements	Time	6.87	3.00	2.21	3.82	1.67	1.23
	Cost	5.09	2.17	1.63	3.88	1.67	1.25
	Quality	3.50	1.50	1.12	2.54	1.00	0.82
Financial status	Time	8.46	3.67	2.72	4.71	2.17	1.51
	Cost	6.04	2.67	1.94	3.69	1.50	1.19
	Quality	4.45	2.00	1.43	3.18	1.33	1.02
Experience	Time	7.31	3.17	2.35	4.58	2.00	1.47
	Cost	6.68	2.83	2.15	3.75	1.67	1.21
	Quality	5.72	2.50	1.84	3.31	1.50	1.06
Plant and equipment	Time	6.04	2.50	1.94	3.82	1.67	1.23
	Cost	5.41	2.33	1.74	2.61	1.17	0.84
	Quality	3.50	1.50	1.12	1.72	0.67	0.55
Technical personnel	Time	4.77	2.17	1.53	3.94	1.83	1.27
	Cost	4.45	1.83	1.43	3.94	1.67	1.27
	Quality	3.94	1.67	1.27	3.31	1.50	1.06
Ability	Time	7.63	3.33	2.45	3.82	1.67	1.23
	Cost	6.68	3.00	2.15	3.18	1.33	1.02
	Quality	6.68	2.83	2.15	3.50	1.50	1.12
Past performance	Time	7.06	3.17	2.27	4.90	2.17	1.57
	Cost	5.15	2.17	1.66	3.62	1.67	1.16
	Quality	5.91	2.67	1.90	3.62	1.67	1.16
Project management organization	Time	6.68	3.00	2.15	5.28	2.33	1.70
	Cost	4.77	2.00	1.53	3.62	1.67	1.16
	Quality	5.21	2.17	1.68	3.31	1.50	1.06
Management personnel	Time	7.63	3.33	2.45	4.26	2.00	1.37
	Cost	4.96	2.17	1.59	4.13	1.67	1.33
	Quality	4.77	2.17	1.53	3.75	1.67	1.21
Management knowledge	Time	6.04	2.67	1.94	3.82	1.67	1.23
	Cost	5.41	2.33	1.74	3.94	1.67	1.27
	Quality	5.41	2.33	1.74	3.12	1.33	1.00
Safety performance	Time	2.48	1.17	0.80	1.84	0.83	0.59
	Cost	1.84	0.83	0.59	1.53	0.67	0.49
	Quality	0.25	0.17	0.08	0.57	0.17	0.18
Experience modification rate	Time	2.16	1.00	0.69	1.34	0.50	0.43
	Cost	2.16	1.00	0.69	1.34	0.50	0.43
	Quality	1.08	0.33	0.17	0.70	0.33	0.22
OSHA incidence rate	Time	2.54	1.17	0.82	1.78	0.67	0.57
	Cost	1.59	0.67	0.51	1.46	0.67	0.47
	Quality	0.00	0.00	0.00	0.06	0.00	0.02
Management safety accountability	Time	0.70	0.33	0.22	0.00	0.00	0.00
	Cost	0.70	0.33	0.22	0.00	0.00	0.00
	Quality	0.64	0.33	0.20	0.38	0.22	0.12
Past failures	Time	4.77	2.00	1.53	5.02	2.17	1.61
	Cost	6.99	3.00	2.25	3.82	1.67	1.23
	Quality	5.09	2.17	1.63	3.82	1.67	1.23
Length of time in business	Time	2.86	1.33	0.92	2.16	1.00	0.69
	Cost	1.91	0.83	0.61	3.12	1.33	1.00
	Quality	3.18	1.33	1.02	2.80	1.33	0.90
Owner/contractor relationship	Time	3.82	1.67	1.23	3.75	1.67	1.21
	Cost	6.04	2.67	1.94	3.31	1.50	1.06
	Quality	4.13	1.83	1.33	2.16	1.00	0.69
Other relations	Time	4.77	2.17	1.53	3.82	1.67	1.23
	Cost	5.09	2.17	1.63	3.18	1.33	1.02
	Quality	3.82	1.67	1.23	2.86	1.17	0.92

Table 3 Rank order of the ten criteria with largest expected values

Contractor selection criteria	Expected value
(a) Time	
Past failures	113
Management personnel	112
Financial status	112
Bank arrangements	111
Ability	111
Management knowledge	111
Project management organization	110
Experience	110
Other relations	110
Past performance	109
(b) Cost	
Past failures	114
Financial status	111
Credit rating	110
Experience	110
Financial stability	108
Ability	108
Bank arrangements	108
Management personnel	108
Other relations	108
Owner/contractor relationship	107
(c) Quality	
Past failures	89
Financial status	90
Technical personnel	91
Ability	92
Past performance	92
Management knowledge	92
Management personnel	92
Project management organization	92
Experience	93
Financial stability	93

Table 4 Rank order of the ten criteria with lowest expected values

Contractor selection criteria	Expected value
(a) Time	
Management safety accountability	102
Experience modification rate	102
Length of time in business	102
Safety performance	103
OSHA incidence rate	103
Owner/contractor relationship	105
Credit rating	107
Financial stability	108
Technical personnel	109
Plant and equipment	109
(b) Cost	
Management safety accountability	102
OSHA incidence rate	102
Length of time in business	102
Safety performance	102
Experience modification rate	102
Plant and equipment	106
Management knowledge	106
Technical personnel	107
Past performance	107
Project management organization	107
(c) Quality	
Management safety accountability	100
Safety performance	100
OSHA incidence rate	100
Experience modification rate	99
Plant and equipment	97
Owner/contractor relationship	96
Length of time in business	96
Credit ratings	95
Bank arrangements	95
Other relations	93

set for the project. *Technical personnel* is the only criterion that appears in quality, indicating the importance placed on technical personnel in achieving the quality standard.

Lowest-rated CSC by expected values

Table 4 gives the ten questionnaire CSCs that had the lowest expected values, ranked in ascending order for each group. The only one criterion agreed upon that comes at the top of the list as having a small effect on time and cost and no effect on quality is *management safety accountability*. The other two CSCs that have a small effect on time and cost and no effect on quality are *safety performance* and *OSHA incidence rate*. *Experience modification rate* has a small effect, from 1 to 2%, on the three project objectives It can be concluded that these four CSCs, which are all related to safety issues, are not important, and all are considered to have a small to no effect on time, cost and quality. This conclusion is substantiated by the fact that none of the interviewees had experienced, directly or indirectly, these CSCs as causing any problems in terms of time, cost and quality, although it is of course a legal requirement that contractors provide the necessary safety policy. Despite the high cost associated with selecting an unsafe contractor (Samelson and Levitt, 1982; Russell, 1992, referring to Business Roundtable, 1982b), safety issues are clearly still not regarded as an important criterion that might affect the progress and budget of the work.

Length of time in business appears in the list for the

three objectives, and it has a small effect on time and cost (2%) and a moderate effect on quality (4%), *Plant and equipment* was found to have a high effect (9%) on time, but a moderate (6%) to small (3%) on cost and quality, indicating the importance of plant and equipment being available at any time needed to avoid delays on project time schedules in the first instance with increased cost and reduced quality later.

In comparing the three groups further, it is interesting to note their commonalities. The *owner/contractor relationship* criterion appears in the list of the lowest expected values for time and quality and also at the bottom of the list in the highest expected values for cost, with a moderate effect on cost and time (7%) and little effect on quality (4%). *Credit ratings* has a moderate effect on time (7%) and quality (5%), indicating the importance of investigating the relationship between main contractors and subcontractors/suppliers in terms of payment and honesty, confirming the findings of Birrell (1985) and Cheetham and Lewis (1993). The three PSFs are affected moderately by the *technical personnel* criterion, as it appears in the lowest ten list for time and cost (with 9% and 7%) and in the highest ten list (with 9%) for quality, indicating that the criterion lies in the middle for the three PSFs and has an almost equal effect.

In contract, in the lowest expected value list, there are some CSCs that appear against one of the project objectives but not others. *Financial stability*, with a moderate effect of 8%, appears in the time list only. *Management knowledge*, *past performance* and *project management organization*, which all are related to the management capabilities of the contractor, appear in the lowest expected value cost list only, having a moderate effect (6–7%), but in the highest list, with a highly moderate effect from 8 to 10%, for time and quality. *Bank arrangements* and *other relations* appear in the quality list only, but with little effect.

Table 5 Rank order of the ten criteria with largest variance values

Contractor selection criteria	Variance value
(a) Time	
Financial status	13.44
Management personnel	11.11
Ablity	11.11
Experience	10.00
Past performance	10.00
Bank arrangements	9.00
Project management organization	9.00
Credit rating	9.00
Management knowledge	7.11
Financial stability	7.11
(b) Cost	
Credit rating	10.0
Past failures	9.00
Financial stability	9.00
Ability	9.00
Experience	8.00
Financial status	7.11
Owner/contractor relationship	7.11
Plant and equipment	5.44
Management knowledge	5.44
Bank arrangements	4.69
(c) Quality	
Ability	8.00
Past performance	7.11
Experience	6.25
Past failures	4.69
Project management organization	4.69
Management personnel	4.69
Financial stability	4.69
Management knowledge	4.44
Financial status	4.00
Credit rating	4.00

Highest-rated CSCs by variance values

The ten CSCs with the largest and smallest variance values for the undesirable contractor are presented in Tables 5 and 7. The variance values in the two lists range from 0 to 15. For the sake of consistency in the explanation and comparison between CSC in the two lists, variance values from 0 to 5 are considered to be very small to small, 5.1 to 10 moderate to high moderate, and 10.1 to 15 high to very high.

Table 5 presents the CSCs with the highest values ranked in decreasing order for time, cost and quality. In this list, six common CSCs appear in the top ten for time, cost and quality, with *financial status* being the major risk variance factor, with a very high (13.44) effect on time but only a moderate and small effect on cost and quality. The second criterion with a relatively high degree is *ability*, with high, to high moderate and high moderate for time, cost and quality respectively. *Experience* takes the third place, with high moderate, high moderate and moderate for the three PSFs. The other three CSCs that appear in all three PSFs are *credit rating*, *management knowledge* and *financial stability*, with the results indicating that time and cost are affected by *credit ratings* (9% and 10%) while quality scored 4% only. *Management knowledge* is important for time, but has a small effect on cost and quality, while *financial stability* is considered to have a moderate effect on time and cost and a relatively small effect on quality. Thus it can be concluded that the most dominant CSCs in terms of variance values that affect PSFs are *financial status*, *credit rating* and *financial stability*, which all relate to the financial soundness

Table 6 Effect of CSCs on PSFs

PSF	CSC and its effects				
	Management personnel	Past performance	Bank arrangements	Project management organization	Past failures
Time	High	High moderate	High moderate	High moderate	–
Cost	–	–	Small	–	High moderate
Quality	Small	Moderate	–	Small	Small

Table 7 Rank order of the ten criteria with lowest variance values

Contractor selection criteria	Variance value
(a) Time	
Management safety accountability	0.11
Experience modification rate	1.00
Safety	1.36
OSHA incidence rate	1.36
Length of time in business	1.78
Owner/contractor relationship	2.78
Past failures	4.00
Technical personnel	4.69
Other relations	4.69
Plant and equipment	6.25
(b) Cost	
Management safety accountability	0.11
OSHA incidence rate	0.44
Safety performance	0.69
Experience modification rate	0.69
Length of time in business	1.00
Technical personnel	3.36
Project management organization	4.00
Other relations	4.69
Past performance	4.69
Management personnel	4.69
(c) Quality	
OSHA incidence rate	0.00
Safety performance	0.03
Management safety accountability	0.11
Experience modification rate	0.11
Length of time in business	1.78
Plant and equipment	2.25
Bank arrangements	2.25
Other relations	2.78
Technical personnel	2.78
Owner/contractor relation	3.36

of the contractor, in addition to the technical CSCs of *experience* and *ability*, followed by that of *management knowledge*.

In a further comparison of the three groups, it was found that some CSCs are common to two PSFs, with different degrees of importance. Table 6 shows these CSCs and their degrees of effect in different PSFs. This indicates that the CSCs *management personnel*, *past performance* and *project management organization* are important for time and quality but not for cost, while *bank arrangements*, which is a measure of the financial soundness of a contractor, is found to be as an important factor for time and cost, strengthening the conclusion that financial soundness is very important. *Past failures* is also important for cost and quality, but it is interesting to note that none of the safety issues are included in the top ten list.

Lowest-rated CSCs by variances values

Table 7 presents the ten questionnaire CSCs with the lowest variance values, ranked in ascending order for each group. The most common clear CSC at the top of the list for time, cost and quality is the safety CSC (*safety*, *experience modification rate*, *OSHA incidence rate* and *management safety accountability*), with these four CSCs having a very small (0–1.36) effect compared with the others. The *length of time in business* also has a very small (1.78) effect, and appears in fifth place for time, cost and quality. *Technical personnel* and *other relations* have quite a considerable effect (4–4.69) on time and cost, but a small effect (2.78) on quality.

The results also show that *owner/contractor relation* and *plant and equipment* have some effect on time and quality, with the technical personnel having a moderate effect on time despite being in the lowest ten. In addition there are some CSCs that appear in one of the groups but not in the other, although their effects are small.

Overall, in comparing the CSC for the three PSFs, it appears that time is the most sensitive, being affected by three CSCs of a high to a very high degree, 8 CSC of moderate to high moderate, and 9 CSC of small to very small. This is followed by cost, which is affected by 9 CSCs of moderate to high moderate, and 11 CSCs of small to very small. Finally, the quality PSF is affected by only three CSCs of moderate degree and

Table 8 Correlation coefficient between criteria for time

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
Q1	1.00	0.37	0.25	0.01	0.19	−0.04	−0.11	−0.27	0.48	−0.31	0.34	−0.15	−0.69	−0.68	−0.69	−0.25	−0.63	−0.49	–	−0.40
Q2		1.00	0.39	−0.30	−0.13	−0.91	−0.06	−0.32	−0.24	−0.70	−0.39	−0.92	0.20	0.13	0.20	0.56	−0.69	−0.31	–	−0.80
Q3			1.00	0.67	0.84[c]	−0.22	0.19	0.64	0.65	−0.22	−0.06	−0.19	0.20	0.24	0.34	−0.37	−0.19	−0.83	–	−0.67
Q4				1.00	0.91[b]	0.45	0.61	0.93[a]	0.76[b]	0.54	0.53	0.50	0.11	0.24	0.11	−0.70	0.49	−0.75	–	0.10
Q5					1.00	0.33	0.29	0.82[c]	0.90[c]	0.20	0.30	0.32	−0.05	0.05	0.15	−0.79	0.18	−0.77	–	−0.25
Q6						1.00	0.14	0.32	0.51	0.72	0.63	0.88[c]	−0.49	−0.40	−0.34	−0.79	0.62	0.08	–	0.69
Q7							1.00	0.51	0.08	0.73[c]	0.70	0.18	0.30	0.41	0.09	−0.07	0.62	−0.51	–	0.39
Q8								1.00	0.58	0.45	0.25	0.50	0.42	0.52	0.30	−0.53	0.50	−0.63	–	0.09
Q9									1.00	0.16	0.42	0.43	−0.44	−0.35	−0.23	−0.91	0.02	−0.67	–	−0.18
Q10										1.00	0.79[c]	0.68	−0.02	0.11	−0.07	−0.40	0.92[b]	−0.06	–	0.85
Q11											1.00	0.51	−0.43	−0.30	−0.49	−0.50	0.50	−0.38	–	0.56
Q12												1.00	−0.16	−0.07	−0.40	−0.62	0.56	−0.03	–	0.72
Q13													1.00	0.99[a]	0.63	0.52	0.21	−0.08	–	−0.05
Q14														1.00	0.62	0.43	0.31	−0.16	–	0.02
Q15															1.00	0.18	0.30	0.10	–	−0.26
Q16																1.00	−0.31	0.37	–	−0.13
Q17																	1.00	0.12	–	0.77[c]
Q18																		1.00	–	0.38
Q19																			–	–
Q20																				1.00

[a] Significant at 0.001 level;
[b] significant at 0.01 level;
[c] significant at 0.05 level;
– = undefined
Q1 = Financial stability
Q2 = Credit rating
Q3 = Bank arrangements
Q4 = Financial status
Q5 = Experience
Q6 = Plant and equipment
Q7 = Technical personnel
Q8 = Ability
Q9 = Past performance
Q10 = Project management
Q11 = Management personnel
Q12 = Management knowledge
Q13 = Safety performance
Q14 = Experience modification rate
Q15 = OSHA incidence rate
Q16 = Management safety accountability
Q17 = Past failures
Q18 = Length of time in business
Q19 = Owner/contractor relationship
Q20 = Other relations

Table 9 Correlation coefficient between criteria for cost

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
Q1	1.00	0.33	0.75[c]	0.69	0.33	−0.65	−0.25	−0.01	0.02	−0.09	0.07	−0.50	−0.58	−0.03	−0.42	−0.57	−0.03	−0.91	−0.11	−0.10
Q2		1.00	0.20	0.57	0.84[c]	0.01	0.35	0.71	0.82[c]	−0.14	0.26	0.18	−0.45	−0.84	−0.28	−0.40	0.05	−0.48	−0.26	−0.36
Q3			1.00	0.16	0.41	−0.90	−0.47	−0.19	−0.07	−0.46	−0.41	−0.83	−0.18	0.15	0.03	−0.16	−0.46	−0.52	−0.52	−0.47
Q4				1.00	0.50	−0.19	0.42	0.54	0.38	0.14	0.61	−0.01	−0.50	−0.34	−0.38	−0.45	0.28	−0.81	0.40	0.31
Q5					1.00	−0.40	0.46	0.75[c]	0.72	−0.34	0.20	−0.25	−0.01	−0.53	0.22	0.06	−0.32	−0.34	−0.14	−0.23
Q6						1.00	0.23	0.11	0.19	0.46	0.28	0.96[a]	−0.15	−0.41	−0.35	−0.19	0.54	0.38	0.17	0.14
Q7							1.00	0.89[b]	0.65	0.37	0.82[c]	0.36	0.37	−0.41	0.37	0.39	−0.12	0.18	0.71	0.63
Q8								1.00	0.90[b]	0.26	0.73[c]	0.31	0.12	−0.71	0.20	0.13	−0.20	−0.06	0.37	0.30
Q9									1.00	0.30	0.58	0.40	−0.07	−0.91	0.01	−0.10	−0.28	−0.07	0.01	0.00
Q10										1.00	0.76[c]	0.61	−0.01	−0.32	−0.18	−0.16	−0.09	0.15	0.53	0.67
Q11											1.00	0.48	0.02	−0.45	−0.03	−0.04	−0.01	−0.11	0.77[c]	0.78[c]
Q12												1.00	−0.23	−0.60	−0.40	−0.29	0.44	0.25	0.22	0.21
Q13													1.00	0.40	0.96[a]	0.98[a]	−0.61	0.79[c]	0.33	0.37
Q14														1.00	0.35	0.43	−0.01	0.18	0.17	0.19
Q15															1.00	0.97[a]	−0.69	0.64	0.24	0.25
Q16																1.00	−0.52	−0.70[c]	0.32	0.32
Q17																	1.00	−0.34	0.11	−0.04
Q18																		1.00	0.09	0.16
Q19																			1.00	0.97[a]
Q20																				1.00

[a] Significant at 0.001 level;
[b] significant at 0.01 level;
[c] significant at 0.05 level;
– = undefined
Q1 = Financial stability
Q2 = Credit rating
Q3 = Bank arrangements
Q4 = Financial status
Q5 = Experience
Q6 = Plant and equipment
Q7 = Technical personnel
Q8 = Ability
Q9 = Past performance
Q10 = Project management
Q11 = Management personnel
Q12 = Management knowledge
Q13 = Safety performance
Q14 = Experience modification rate
Q15 = OSHA incidence rate
Q16 = Management safety accountability
Q17 = Past failures
Q18 = Length of time in business
Q19 = Owner/contractor relationship
Q20 = Other relations

Table 10 Correlation coefficient between criteria for quality

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
Q1	1.00	0.70	−0.04	0.70	0.16	0.58	0.40	0.14	−0.23	−0.03	0.52	−0.08	−0.44	−0.22	–	0.70	0.27	0.46	0.41	0.47
Q2		1.00	0.43	0.25	0.21	0.17	−0.16	−0.21	−0.02	−0.64	0.12	−0.55	−0.63	−0.40	–	0.25	−0.09	0.64	0.28	0.19
Q3			1.00	−0.03	0.75[c]	−0.42	−0.11	0.33	0.83[c]	−0.26	0.33	−0.03	−0.55	0.20	–	−0.03	0.29	0.81[c]	0.50	0.27
Q4				1.00	0.21	0.17	0.28	0.57	0.03	0.19	0.81[c]	0.16	−0.63	−0.10	–	1.00[a]	0.23	0.36[c]	0.28	0.19
Q5					1.00	0.13	0.42	0.77[c]	0.90[b]	0.23	0.61	0.22	−0.42	0.16	–	0.21	0.76[c]	0.88[c]	0.92[b]	0.50
Q6						1.00	0.65	0.13	−0.26	0.32	0.10	0.01	0.22	−0.28	–	0.17	0.45	0.10	0.50	0.39
Q7							1.00	0.52	0.14	0.84[c]	0.58	0.74[c]	0.32	0.50	–	0.28	0.9[b]	0.21	0.68	0.84[c]
Q8								1.00	0.71	0.57	0.82[c]	0.47	−0.36	0.19	–	0.57	0.72	0.53	0.70	0.33
Q9									1.00	0.15	0.46	0.22	−0.39	0.25	–	0.03	0.55	0.71	0.66	0.25
Q10										1.00	0.49	0.91[b]	0.49	0.65	–	0.19	0.74[c]	−0.14	0.36	0.56
Q11											1.00	0.55	−0.48	0.36	–	0.81[c]	0.68	0.59	0.63	0.59
Q12												1.00	0.42	0.90[b]	–	0.16	0.69	−0.08	0.27	0.66
Q13													1.00	0.42	–	−0.63	0.09	−0.07	−0.26	0.14
Q14														1.00	–	−0.10	0.51	−0.05	0.13	0.65
Q15															–	–	–	–	–	–
Q16																1.00	0.23	0.36	0.28	0.19
Q17																	1.00	0.52	0.88[c]	0.84[c]
Q18																		1.00	0.81[c]	0.46
Q19																			1.00	0.69
Q20																				1.00

[a] Significant at 0.001 level;
[b] significant at 0.01 level;
[c] significant at 0.05 level;
– = undefined

17 of small to very small degree.

Relationships between CSCs

Using the expected mean values of the six people interviewed, the correlation coefficients between the 20 CSCs listed in the questionnaire were obtained, and these are presented in Tables 8–10 for time, cost, and quality respectively. The corresponding population correlation coefficient (r) was tested for significance at 0.001, 0.01 and 0.05 levels (Speigel, 1980). The CSCs that are statistically significant (i.e. where the population correlation coefficient is significantly greater than 0) at 0.001, 0.01, 0.05 are indicated by a, b and c in the Tables.

For ease of interpretation and explanation, each criterion from the rows was taken as a base, and then this criterion was compared with the whole list of CSCs from the columns. For example, in Table 8, Q3, *bank arrangements*, was strongly associated with *experience*; Q4, *financial status*, was associated with *experience*, *abilitiy*, and *past performance*; Q5, *experience* was associated with *ability* and *past performance*; Q6, *plant and equipment* was associated with *management knowledge*; Q7, *technical personnel* was associated with *project management organization*; Q10, *project management organization* was associated with *management personnel* and *past failures*; and Q13, *safety*, with *experience modification rate*.

Summary and conclusions

In order to invite suitable bidders it is necessary to clarify and develop appropriate predetermined contractor selection criteria (CSCs), improve and organize the assessment of information relating to these, and develop methods for evaluating them against various project success factors (PSFs) in the prequalification and bid evaluation stages of the procurement process. Data were collected by interview from a sample of six experienced construction professionals concerning their views of the effect of the 20 contractor CSCs on the three PSFs of time, cost, and quality. Following a Delphic round and further interviews with two additional and equally experienced construction personnel, it was confirmed that the mean values received were sufficiently representative to become values for further research and any future systems development.

The results of the research indicate that past failures, financial status, financial stability, credit ratings, experience, ability, management personnel, and management knowledge are perceived to be the most dominant CSCs affecting all three PSFs, with safety CSC (Safety, experience modification rate, OSHA incidence rate and management safety accountability) and the length of time in business being perceived to have the least effect overall. It was also found that some CSCs, such as past performance, bank arrangements, project management organization, plant and equipment, are perceived to affect only one or two PSFs. Whether or not these perceptions are universal, or indeed correspond with the true relationships between CSC and PSFs, is a matter for further study.

The results presented provide insight into how time, cost, and quality are differently affected by contractors' capabilities in terms of different CSCs. This can aid owners in reviewing their current prequalification procedures, and can provide them with suggestions for changes in tender evaluation stage if priority is not always to be given to the bid price. The major benefits provided by this study are the documentation of the perceived effects of various CSCs on project objectives, together with the provision of a quantitative technique for contractor selection in terms of their own goals, either for prequalification or bid evaluation.

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Appendix 1: Questionnaire investigating the effect of contractor criteria on project objectives (time, cost, quality)

Q1 What effect does financial stability (financial history) of the contractor have on the following project objectives (time, cost, quality)? Simply give three percentages for each stability case.

	Financially unstable contractor			Financially stable contractor		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q2 What effect does credit ratings (from subcontractors and suppliers) of the contractor have on the following project objectives? Simply give three percentages for each credit case.

	Low credited contractor			High credited contractor		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q3 What effect does bank arrangements and bonding of the contractor have on the following project objectives? Simply give three percentages for each case.

	Insufficient bank arrangements			Sufficient bank arrangements		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q4 What effect does financial status (ratio analysis) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor financial status			Excellent financial status		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q5 What effect does experience (last three to five years) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Inadequate experience			Adequate experience		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q6 What effect does plant and equipment (availability at any time) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Insufficient			Sufficient		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q7 What effect does personnel (availability and experience) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Insufficient			Sufficient		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q8 What effect does ability of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor ability			Excellent ability		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q9 What effect does past performance and quality of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor performance			Excellent performance		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q10 What effect does project management organization of the contractor have on the following project objectives? Simply give three percentages for each case.

	Ineffective			Effective		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q11 What effect does management personnel (key personnel) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Inadequate			Adequate		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q12 What effect does management knowledge (scheduling, cost control, material control, risk avoidance . . .) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor			Excellent		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q13 What effect does safety performance of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor safety performance			Excellent safety performance		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q14 What effect does experience modification rate (accident claims) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor			Excellent		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q15 What effect does OSHA incidence rate (number of injuries and illness) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor			Excellent		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q16 What effect does management safety accountability of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor			Excellent		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q17 What effect does past failures (claims, debarment, failed contract, financial penalties) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor record			Excellent record		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q18 What effect does length of time in business of the contractor have on the following project objectives? Simply give three percentages for each case.

	Newly established			Well established		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q19 What effect does owner/contractor relationship (responsibility and consideration for the client staff and general public) have on the following project objectives? Simply give three percentages for each case.

	Poor relation			Excellent relation		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Q20 What effect do other relationships (subcontractors, suppliers) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor relation			Excellent relation		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time						
Cost						
Quality						

Appendix 2: Questionnaire investigating the effect of contractor criteria on project objectives (time, cost, quality)

Q1 What effect does financial stability (financial history) of the contractor have on the following project objectives (time, cost, quality)? Simply give three percentages for each stability case.

	Financially unstable contractor			Financially stable contractor		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	118	107	102	105	100	95
Cost	118	108	100	105	100	97
Quality	87	93	100	95	100	108

Q2 What effect does credit ratings (from subcontractors and suppliers) of the contractor have on the following project objectives? Simply give three percentages for each credit case.

	Low credited contractor			High credited contractor		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	118	107	100	105	100	92
Cost	122	109	103	104	100	94
Quality	88	95	100	95	100	105

Q3 What effect do bank arrangements and bonding of the contractor have on the following project objectives? Simply give three percentages for each case.

	Insufficient bank arrangements			Sufficient bank arrangements		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	120	111	102	103	100	93
Cost	115	108	102	104	100	94
Quality	90	95	99	98	100	104

Q4 What effect does financial status (ratio analysis) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor financial status			Excellent financial status		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	126	111	104	106	100	93
Cost	120	110	104	103	100	94
Quality	83	90	95	96	100	104

Q5 What effect does experience (last three to five years) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Inadequate experience			Adequate experience		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	119	110	100	105	100	93
Cost	119	109	102	105	100	95
Quality	85	93	100	96	100	105

Q6 What effect does plant and equipment (availability at any time) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Insufficient			Sufficient		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	118	198	193	105	100	95
Cost	114	106	100	103	100	96
Quality	91	97	100	99	100	103

Q7 What effect does personnel (availability and experience) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Insufficient personnel			Sufficient personnel		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	116	108	103	104	100	93
Cost	113	106	102	105	100	95
Quality	85	92	95	96	100	105

Q8 What effect does ability of the contractor have on the following project objectives? Simply give three percentages for each stability case.

	Poor ability			Excellent ability		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	120	111	100	105	100	95
Cost	118	108	100	104	100	96
Quality	83	92	100	95	100	104

Q9 What effect does past performance and quality of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor performance			Excellent performance		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	121	108	102	104	100	91
Cost	114	107	101	105	100	95
Quality	83	93	99	98	100	108

Q10 What effect does project management organization of the contractor have on the following project objectives? Simply give three percentages for each case.

	Ineffective			Effective		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	121	109	103	107	100	93
Cost	114	107	102	105	100	95
Quality	85	92	98	96	100	105

Q11 What effect does management personnel (key personnel) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Inadequate			Adequate		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	124	111	104	105	100	93
Cost	115	108	102	105	100	95
Quality	84	92	97	98	100	108

Q12 What effect does management knowledge (scheduling, cost control, material control, risk avoidance. . .) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor			Excellent		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	121	110	105	105	100	95
Cost	114	105	100	105	100	95
Quality	84	93	98	98	100	106

Q13 What effect does safety performance of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor safety performance			Excellent safety performance		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	107	102	100	102	100	97
Cost	105	102	100	101	100	97
Quality	100	100	101	100	100	101

Q14 What effect does experience modification rate (accident claims) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor			Excellent		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	106	102	100	101	100	98
Cost	106	102	100	101	100	98
Quality	98	99	100	99	100	101

Q15 What effect does OSHA incidence rate (number of injuries and illness) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor			Excellent		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	107	103	100	101	100	97
Cost	104	102	100	101	100	97
Quality	100	100	100	100	100	100

Q16 What effect does management safety accountability of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor			Excellent		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	102	102	100	100	100	100
Cost	102	102	100	100	100	100
Quality	98	100	100	99	100	100

Q17 What effect does past failures (claims, debarment, failed contract, financial penalties) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor record			Excellent record		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	119	113	107	105	100	92
Cost	126	113	108	105	100	95
Quality	82	89	95	96	100	106

Q18 What effect does length of time in business of the contractor have on the following project objectives? Simply give three percentages for each case.

	Newly established			Well established		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	107	100	99	103	100	97
Cost	105	101	100	105	100	97
Quality	92	96	100	96	100	104

Q19 What effect does owner/contractor relationship (responsibility and consideration for the client staff and general public) have on the following project objectives? Simply give three percentages for each case.

	Poor relation			Excellent relation		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	110	105	100	104	100	94
Cost	116	107	100	105	100	96
Quality	89	96	100	98	100	104

Q20 What effect do other relationships (subcontractors, suppliers) of the contractor have on the following project objectives? Simply give three percentages for each case.

	Poor relation			Excellent relation		
	Pessimistic	Average	Optimistic	Pessimistic	Average	Optimistic
	P	*A*	*O*	*P*	*A*	*O*
Time	116	110	103	103	100	93
Cost	114	108	101	105	100	97
Quality	88	93	98	97	100	104

Appendix 3: Expected values, standard deviation and variance of time, cost and quality for two contractors of undesirable and desirable characteristics

Contractor selection criteria	Project success factors	Undesirable contractor			Desirable contractor		
		E	*S*	*V*	*E*	*S*	*V*
Financial stability	Time	108	2.67	7.11	100	1.67	2.78
	Cost	108	3	9	100	1.33	1.78
	Quality	93	2.17	4.7	100	2.17	4.69
Credit rating	Time	107	3	9	100	2.17	4.69
	Cost	110	3.17	10	100	1.67	2.78
	Quality	95	2	4	100	1.67	2.78
Bank arrangements	Time	111	3	9	100	1.67	2.78
	Cost	108	2.17	4.7	100	1.67	2.78
	Quality	95	1.5	2.25	100	1.00	1
Financial status	Time	112	3.67	13.44	100	2.17	4.69
	Cost	111	2.67	7.11	100	1.5	2.25
	Quality	90	2	4	100	1.33	1.78
Experience	Time	110	3.17	10	100	2.00	4
	Cost	110	2.83	8	100	1.67	2.78
	Quality	93	2.5	6.25	100	1.50	2.25
Plant and equipment	Time	109	2.5	6.25	100	1.67	2.78
	Cost	106	2.33	5.44	100	1.17	1.36
	Quality	97	1.5	2.25	100	0.67	0.44
Technical personnel	Time	109	2.17	4.69	100	1.83	3.36
	Cost	107	1.83	3.36	100	1.67	2.78
	Quality	91	1.67	2.78	100	1.50	2.25
Ability	Time	111	3.33	11.11	100	1.67	2.78
	Cost	108	3	9	100	1.33	1.78
	Quality	92	2.83	8	100	1.50	2.25
Past performance	Time	109	3.17	10	100	2.17	4.69
	Cost	107	2.17	4.69	100	1.67	2.78
	Quality	92	2.67	7.11	100	1.67	2.78
Project management -organization	Time	110	3	9	100	2.33	5.44
	Cost	107	2	4	100	1.67	2.78
	Quality	92	2.17	4.69	100	1.50	2.25
Management personnel	Time	112	3.33	11.11	100	2.00	4
	Cost	108	2.17	4.69	100	1.67	2.78
	Quality	92	2.17	4.69	100	1.67	2.78
Management knowledge	Time	111	2.67	7.11	100	1.67	2.78
	Cost	106	2.33	5.44	100	1.67	2.78
	Quality	92	2.33	4.44	100	1.33	1.78
Safety performance	Time	103	1.17	1.36	100	0.83	0.69
	Cost	102	0.83	0.69	100	0.67	0.44
	Quality	100	0.17	0.03	100	0.17	0.03

Contractor selection criteria	Project success factors	Undesirable contractor			Desirable contractor		
		E	*S*	*V*	*E*	*S*	*V*
Experience modification rate	Time	102	1.00	1	100	0.50	0.25
	Cost	102	1.00	1	100	0.50	0.25
	Quality	99	0.33	0.11	100	0.33	0.11
OSHA incidence rate	Time	103	1.17	1.36	100	0.67	0.44
	Cost	102	0.67	0.44	100	0.67	0.44
	Quality	100	0.33	0	100	0.00	0
Management safety accountability	Time	102	0.33	0.11	100	0.00	0
	Cost	102	0.33	0.11	100	0.00	0
	Quality	100	0.33	0.11	100	0.22	0.05
Past failures	Time	113	2.00	4	100	2.17	4.69
	Cost	114	3.00	9	100	1.67	2.78
	Quality	89	2.17	4.69	100	1.67	2.78
Length of time in business	Time	101	1.33	1.78	100	1.00	1
	Cost	102	0.83	0.69	100	1.33	1.78
	Quality	96	1.33	1.78	100	1.33	1.78
Owner/contractor relationship	Time	105	1.67	2.78	100	1.67	2.78
	Cost	107	2.67	7.11	100	1.50	2.25
	Quality	96	1.83	3.36	100	1.00	2
Other relations	Time	110	2.17	4.69	100	1.67	2.78
	Cost	108	2.17	4.69	100	1.33	1.78
	Quality	93	1.67	2.78	100	1.17	1.36

Note: For time and cost, the lower the better, but for quality, the higher the better.