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CONTRACTOR SELECTION USING MULTICRITERIA UTILITY THEORY: AN ADDITIVE MODEL

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ABSTRACT: A systematic multicriteria decision analysis technique is described for contractor selection and bid evaluation based on utility theory and which permits different types of contractor capabilities to be evaluated. A UK case study is used to illustrate the technique. The theoretical basis and the advantages of the technique are also presented.

Keywords: Contractor selection, bid evaluation, prequalification, multicriteria decision-making, utility theory.

INTRODUCTION

In the last two decades, there has been a steady increase in the range of methods used for the procurement of construction work. Despite this, however, there has been no commensurate improvement in the 'success' rate of construction projects [1]. Instead, there have been extensive delays in the planned schedule, cost overruns, serious problems in quality and an increased number of claims and litigation. To improve this situation, still further methods are being sought (following [1]) to improve current tendering procedures and contractor selection.

The practices and procedures for selecting contractors and awarding contracts in the construction industry are based on those used in the public sector and have remained relatively unchanged since the 1940's [2,3,4,5]. These involve systems of bid evaluation dominated by the principle of acceptance of the lowest price [6,7]. Many now believe that the public sector system of bid evaluation, concentrating as it does solely on bid price, is one of the major causes of project delivery problems [2,8,9]. Contractors, when faced with a shortage of work, are more likely to enter low bids simply to stay in business in the short term and in the hope of somehow raising additional income through 'claims' or cutting costs to compensate. From a client's point of view, such contractors are risky. This implies also that the automatic selection of the lowest bidding contractor is also risky - a fact that is seldom appreciated by construction clients. Changing this process, however, is not easy. Most clients, especially those in the public sector, necessarily have to be accountable for their decisions and this becomes more difficult when selecting bidders other than the lowest. This has led researchers to look for techniques for contractor selection which utilise information concerning client objectives and contractor capabilities as well bid price as objectively and transparently as possible as a means of achieving the best value for money.

Except where clients have an identified single criterion, such as a fixed price or fixed completion date, several criteria relating to contractors' likely performance (such as technical experience, structure of the organisation, financial stability, past performance and safety records) need to be considered in selecting contractors. To do this formally involves the use of multicriteria decision analysis methods (see *eg* [10] for a general overview of this well established technique and [11] for a comprehensive account of its use in the construction context). These have been considered previously in contractor selection (*eg* [12,3,13,14,15,16,6,17]).

In this paper we present one such method based on utility theory. This is unique in the context of construction procurement. The theoretical basis of the technique is provided. A case study of an additive model is used to illustrate the technique. This includes details of interviews with a number of construction professionals which elicited the utility functions needed. This approach is new to the field.

The proposed technique is suitable for the evaluation of bids where there are conflicting objectives and for sensitivity testing with several stake-holders [18] - a situation that exists in the predominant method (competitive tendering) of construction procurement in the UK and in all other countries using this method. It may also be used in other applications, including: (1) the selection of construction equipment; (2) pre-qualification of contractors, where bid price is not one of the criteria; and (3) the selection of construction and project managers.

CURRENT EVALUATION PRACTICES

By far the most frequently used method of selecting construction contractors is by competitive bidding, in which the lowest bidder is awarded the contract. Many countries have introduced modifications, involving clearly defined procedures for bid evaluation, to this "lowest bidder" criterion [3,4,12,19]. The variations in these procedures, however, still serve the common objective of selecting a qualified contractor on a competitive basis. In Denmark, for example, the two highest and the two lowest tenders are excluded and the closest to the average of the remaining bids is selected. A similar procedure is used in Italy, Portugal, Peru, and South Korea, but with only the lowest and highest being excluded [3]. In Saudi Arabia, the lowest bidder is selected provided that the bid is not less than 70% of the owner's cost estimate [20]. In Canada and the USA, especially in the public sector, the "lowest bidder" is selected, but a bid bond in an amount equal to 10% of the bid price also has to be provided [21,22]. The French practice is to exclude bids which appear to be abnormally low [23]. In all cases, bid prices are the sole basis for contractor selection and competition.

Reliance on bid prices alone as the discriminating factor between bidders is, however, somewhat risky and short-sighted. The lowest bidder may not be the most economic choice in the long term as the client runs the risk of poor performance by that contractor during the project life. What is required is a broader evaluation technique that takes into account these risks when contractors are selected through an examination of other, non-price, data concerning the individual contractors involved [24]. Multicriteria methods are available for this but these can encounter some difficulties when comparing different criteria measured on different scales. Various ways have been suggested to overcome these problems by combining criteria values into a single scale. Hardy's [12] criterion for example is the bid which maximises the return on the client's investment. Thus he proposes that bidders should submit a schedule of the payments they expect to fall due to them during the contract. Both the client and contractor may use this to determine the Present Value of bids. Ellis and Herbsman [8] on the other hand propose a time/cost approach to determine the winning bidder in highway construction contracts. This involves applying a 'road user cost' to the contract time proposed by each bidder. By this method the criteria to be considered are bid prices and contract time (the road user cost being applied to the contract time) and, by converting the contract time to a cost to the client, a straightforward comparison can be made on a single criterion. Finally, Holt *et al* [13] combine what they term P2 scores (representing the scores of the information collected) and their P3 scores (representing the bid price) into a simple index by assigning a 40% weighting for the P2 scores and a 60% weighting to the P3 scores.

MULTIPLE OBJECTIVE DECISION MAKING

Decision analysis is concerned with situations in which decision-makers have to choose among several alternatives A_1, A_2, ..., A_n through the consideration of a common, but differently scored, set of attributes (criteria) for each alternative. Traditionally, the criteria scores are manipulated in such a way as to provide a consequence describable in terms of single criterion making it an easy task for the decision-maker to choose the most desirable alternative.

Profit maximisation has long been considered to be the prime objective of contract bidding strategies and has been a popular single criterion in use. In recent years, however, there has been a growing awareness that, whilst most decision-makers are interested in maximising profits, they are also concerned with other objectives such as corporate goodwill, market share, and future growth.

Selection of a construction contractor is also a decision characterised by multiple objectives. Owners want to minimise the likely cost of projects, but they also want contractors to maintain schedules as well as achieving acceptable quality standards.

Unidimensional Utility Theory

Utility is a measure of desirability or satisfaction and provides a uniform scale to compare and/or combine tangible and intangible criteria [25]. A utility function is a device which quantifies the preferences of a decision-maker by assigning a numerical index to varying levels of satisfaction of a criterion [26]. For a single criterion (**X**), the utility of satisfaction of a consequence x' is denoted by u(x'). Utility functions are so constructed such that u(x') is less preferred to u(x") i.e u(x') < u(x"), if and only if x' is less preferred to x" i.e x' < x". In other words, a utility function is a transformation of some level of contractor performance, x^i, measured in its natural units into an equivalent level of decision-maker satisfaction, as shown in Fig 1.

Theoretically, decision-makers comprise three types: risk averse, risk neutral, and risk prone as shown in Fig 2a, 2b, and 2c respectively, the decision-maker's risk attitude being reflected in the shape of the utility curve which combines the decision-maker's preference attitudes, ie., increasing or decreasing utility with increasing x^i.

Multi-Criteria Additive Utility Function

All decisions involve choosing one, from several, alternatives. Typically, each alternative is assessed for desirability on a number of scored criteria. What connects the criteria scores with desirability is the utility function.

The most common formulation of a multicriteria utility function is the additive model [18]:

$$U_i = \sum_{j}^{m} w_j U_{ij} \;\; for all i \; 1$$

where

U_i is the overall utility value of alternative i

u_{ij} is the utility value of the j^{th} criterion for the i^{th} alternative

U_{ij} $= u(X_i)$, for $1 \geq i \geq n$ and $1 \geq j \geq m$

X_i $= (x_{ij})$, for $1 \geq i \geq n$ and $1 \geq j \geq m$. X_i designates a specific value of x_{ij}.

n is the total number of criteria

m is the total number of alternatives

w_j is the relative weight of the j^{th} criterion

The advantage of an additive form is its simplicity. In order to determine the overall utility function for any alternative, a decision-maker need only determine *n* unidimensional utility functions for that alternative.

Multicriteria utility theory generally combines the main advantages of simple scoring techniques and optimisation models. Further, in situations in which satisfaction is uncertain, utility functions have the property that expected utility can be used as a guide to rational decision-making.

To illustrate the use of multicriteria utility theory in contractor selection, the next section proceeds to demonstrate the development of an additive utility model by a hypothetical case study.

HYPOTHETICAL CASE STUDY

A multi-storey building project is considered in which the owner's cost estimate is £4.5 million with a 28 week planned construction period. Several potential bidders have been subjected to a preliminary and detailed investigation by examination of their files, past records with the client, technical referees' reports, creditor reports and site visits. As a result, five contractors (A, B, C, D and E) have been pre-qualified. The five contractors' bids are shown in Table 1. At this point, according to the traditional approach, arithmetical checks would be made and the contract would be awarded to contractor E (£4.2 million), the lowest bidder.

Now it is often argued that, as the bidders have already passed the preliminary screening (prequalification), they should all be treated as equal ('level playing-field') and therefore the decision of contract award should be based solely on the one remaining criterion *ie* project cost (bid price). This, however, does not guarantee that the contractor with the lowest bid price is the best for the job. Many things happen over the course of a construction contract - escalation, disputes, financial difficulties, etc. It is quite possible that one or more of the other bidders could complete the project quicker, with a better standard of work and even cheaper at the end of the day.

To establish the likelihood of this involves taking into account the capabilities of the bidders in addition to the bid price. As the main foci of attention of any construction project are usually its completion time, level of quality and final cost, a method of comparing bidders is needed which takes these into account and permits the selection of the contractor with the best overall potential to perform and complete the job satisfactorily.

Contractor Selection Criteria (CSC)

A variety of criteria has been proposed to date for contractor selection (*eg* [2,6,27,28]). Most recently, it has been shown that, in addition to the bid price, there are five main criteria used in practice to assess the likely performance of contractors [29]. These comprise financial soundness, technical ability, management capabilities, safety performance, and reputation. Each of these five criteria is broken down into four sub-criteria to give a total of 20 criteria (Table 2).

Scores of criteria

There is no common method of assessing the 20 criteria in practice. Most are intangible and involve some degree of subjective assessment. There are some criteria, however, where practitioners use a common approach *eg* the use of ratio analysis for assessing the financial soundness of the contractor.

A point score system is used here: 0-4=very poor; 5-8=poor; 9-12=good; 13-16=very good; 17-20=excellent. This is a similar system to that reported as being used by clients [31]. It is flexible enough to differentiate between different levels of likely performance between bidders as well as allowing utility curves to be constructed.

Some of the criteria are negatively oriented in terms of desirability. An example of this is the "past failures" criterion. Here, a higher score indicates that the bidder has many failures in previous projects. For ease of comparison, and to make the scoring consistent for all criteria, the scores in these situations were deducted from 20. For example, assume bidder A has scored 5 points indicating that the bidder has few past failures. The score of the bidder A in this case is converted to 20 - 5 = 15. Thus, higher scores consistently indicate better bidders for all criteria. The only exception to this is the bid price criterion. This is also negatively oriented, as lower bids are more desirable than higher bids, but no change is made to the values submitted by the bidders. The decision-maker, therefore, has to be very careful when assigning values for the utility function in relation to this variable as lower bid prices must receive a higher utility values.

Table 3 shows example scores for the twenty criteria for each bidder together with the bid prices. The average score can be used to compare bidders' scores. For example, the average score of 14.5 for the financial criteria for bidder A is calculated as follows:

Criterion {5}+{6}+{7}+{8} divide by four

$$(12 + 14 + 15 + 17)/4 = 14.5$$

Table 4 shows the average score for all five bidders together with their bid prices.

The profile of the scores of the five bidders is shown in Fig 3. It can be clearly seen that bidder E has the best score for criterion **1** (4.2 million). A closer look at the scores for the other criteria, however, indicates that bidder E is generally inferior to the other bidders. This provides a first indication that bidder E may not be the best contractor for the project and also suggests the need for the other criteria to be taken into account.

Assessment of relative weights

To accommodate the needs of the client and the project, relative weights need to be assigned to the main criteria. This is done by first ranking the criteria in order of importance. A relative weighting is then applied. This is on a scale of 0 to 1 (Table 5) and is applied in such a way that the weights add to unity [18]. The relative weights of the sub-criteria are then applied using the same procedure (see Table 6). The overall weights, or scaling factor, of all the criteria in this case study are shown in a hierarchical structure in Fig 4.

Determination of utility functions

Utility functions can be developed by a technique known as 'standard gambling'. For the construction of the utility functions in this example, the decision-maker's preferences for gambles are analysed by the method suggested by Bell *et al* [30] and Keeney and Raiffa [18].

The first step involves the identification of the **best** and **worst** outcomes (criteria scores) for each one of the criteria. The decision-maker is free to set these utility values at any level provided the best outcome has the higher value. The usual method is to assign the worst outcome a utility value of zero and the best outcome a utility value of unity. This establishes the range of utility values to be from 0 to 1 between the worst and the best possible outcomes. To determine the utility of intermediate values, the decision-maker is offered the following options.

1 Certain option: In this case the decision-maker is offered a **certain** outcome with a probability p=1.

2 Risk option: In this case the decision-maker is offered a

probabilistic outcome in the form of a gamble, in which the decision-maker either receives the best outcome with a probability p or the worst outcome with a probability of 1-p.

The following is an example of how the utility values for criterion *{10} plant and equipment*, with a relative weight of 4.5% or 0.045 (see Fig 4), are obtained and from which a utility curve is established.

***Criterion {10} Plant and equipment*:** The scores of the five bidders for this criterion are shown in Table 7.

The first step is to identify the best and worst outcomes for this criterion and assign arbitrary utility values of 1 for the best outcome (bidder D with 18 points) and 0 for the worst outcome (bidder C with 10 points) as shown in Table 8. The utility of the intermediate values is then determined by offering the decision-maker a choice between the following lotteries (see Fig 5):

Lottery 1: go to route R1 for a certain consequence of 13 points for the plant and equipment criterion

Lottery 2: go to route R2 for either a best consequence of 18 points (bidder D) with a probability of p or a worst consequence of 10 points (bidder C) with a probability of 1-p.

For the decision-maker to make a good decision and choose from the two routes, the utility value of the 13 point score must be assessed and compared with the expected utility of the risk option. What utility value should the decision-maker assign to the certain outcome of the 13 points score? To do this, the decision-maker determines a relative preference for a 13 point consequence by finding the probability p for the best outcome (18 point score) see Fig 5, **to which the decision-maker is indifferent**, between the certain route R1 for a 13 point outcome and the gamble route R2 for the two possible outcomes of 18 and 10 points.

Suppose, after some mental trial and error, the decision-maker judges the indifference probability to be p=0.5 *ie* representing indifference between a certain 13 points outcome and a 50-50 risk between 18 and 10 points. This indifference (at p=0.5) allows the utility value of 13 points, *ie* U(13), to be found from the principal of expected values [31] and from the probability theory. The expected utility from the route R2 of the 50-50 gamble is p x (utility of best outcome score) + (1-p) x (utility of worst outcome) *ie* 0.5 U(18) + (1-0.5) U(10) = 0.5(1) + 0.5(0) = 0.5. Since the decision-maker is indifferent between 13 points for certain and this gamble, the alternatives must have the same utility value, that is U(13) = 0.5.

This procedure can be used for any scores between 10 and 18 - the more utility values obtained, the better the utility curve appears. Table 9 summarises the utility values obtained for different scores for *criterion {10} plant and equipment* and Fig 6 shows the resulting utility curve, in which the criteria scores are plotted against the utility values. Once the utility, or preference, curve for this specific decision-maker is constructed, the utility value for any score between 10 and 18 points can be interpolated directly from the curve.

Appendix A provides details of a real interview conducted with one of the four professionals involved in this case study, aimed at building a utility function for *criterion {10} plant and equipment*. The 13 point score only is shown. This procedure was applied for each criterion and utility values assigned to each criterion. Table 10 summarises the utility values obtained in this way for the whole criteria set.

Selection of the best bidder

All the elements needed for the selection of the best bidder are now known: the list of criteria is defined; the scores of the bidders' achievements in these criteria have been assigned; the relative weights of the criteria have been determined; and the utility values of the decision-maker for these criteria have been defined and drawn.

The next step is to determine the overall utility of each contractor. This is shown in Table 11 for one decision-maker using the additive model. It can be clearly seen that **bidder B** has the highest utility of **(0.857)** and is therefore considered the best bidder for this project. Table 12 shows the overall utility values for the five bidders by the four decision-makers used in this case study. The overall utility values of the other decision-makers confirmed **bidder B** to have the highest overall utility value and therefore to be ranked first. It should be noted that **bidder E**, who submitted the lowest bid price, is ranked only third by this method.

CONCLUSION

There is a need for a contractor selection technique that is capable of considering multiple criteria. Multicriteria utility theory provides one such approach and is especially useful as it allows the treatment of both quantitative and qualitative criteria and in situations where there are several stake-holders.

An additive model of utility technique is chosen for its simplicity, practicality and appropriateness in risky choice situations. The utility model uses utility curves to represent the relationship between the specific capability of a contractor and the value of that capability in risky situations. The individual importance of each contractor criterion is specified using a weighting which also incorporates the risk of the decision-maker.

A hypothetical case study is described to illustrate the method and in which real interviews with four leading professionals involved in contractor selection were conducted for building the utility functions. The precise assessment of the relative weights was shown to have a crucial bearing on the solution.

Multicriteria utility analysis is a technique for use in evaluation decisions where criteria are of different characteristics and appears to be eminently suited to construction contractor selection.

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APPENDIX A: AN INTERVIEW WITH MR OZTASH FOR BUILDING A UTILITY FUNCTION.

The best thing to do is to start by taking any criterion and we see how we can build a utility function for it, let us take criterion number {10}.

Utility function for the criterion {10} - Plant and equipment

Let us start together by taking criterion number {10} plant and equipment which is a sub-criterion of the technical ability criterion. The scores of the five bidders and the weight assigned for this criterion is shown in Table A1. Let us see why we include this criterion, what each of the bidders has scored then we will continue building the utility function of your preferences.

This criterion is included to verify that the equipment required for the execution of the work is available at any time during the construction process. The measurement of this criterion can be traced by the availability of construction equipment at any time, adequate plant and equipment to do the work properly and expeditiously, small tools and, the testing equipment.

Contractor	A	B	C	D	E
Plant and equipment score (points) weight= 0.045	13	14	10	18	16

Table A1: Scores of the five bidders in criterion {10}

The principal of utility theory states that we should assign 1 for the best outcome and 0 for the worst outcome. We will now start together building the utility function for scores between 10 and 18, starting at 13 points.

Utility value for 13 points score. It is better if you refer to the scores in Table A1 and to the Figure A1 to assist you in answering the following question

<u>Questionnaire</u>

Q1. Since you have been told about the principal of utility theory, which of the contractors do you think should receive 1 and which of the contractors do you think should receive 0

Ans. Bidder D, with an 18 point score, will be assigned a utility value u=1. Bidder C, with a 10 point score, will be assigned a utility value u=0

Q2. You are offered two routes (refer to the Figure A). The first route is R1 and will give you an outcome score of 13 points for sure *ie* with a probability p=1.

The second route is R2. Here, you either receive the best outcome of 18 points which has a utility u=1 with a probability p which is so far unknown or you will get the worst outcome of 10 points which has a utility u=0 with a probability of (1-p). Which route you will go for?

Ans. It is difficult choice because I don't know what is the probability of getting the best outcome and the probability of getting the worst outcome from the route R2.

Q3. Let us assume that there is a probability of 0.3 of getting the best outcome and a probability of 0.7 of getting the worst outcome from the route R2. Which route would you prefer in this case - R1 or R2 ?

Ans. Since P= 0.3, it seems to me that the chance of getting the best outcome from route R2 is very small, so in this case I will not gamble. I prefer to choose route R1 with a 13 point certain outcome.

Q4. Now let us assume that there is a probability of 0.9 of getting the best outcome and a probability 0.1 of getting the worst outcome from route R2, which route do you now prefer?

Ans. Since p = 0.9, in this case there is a high chance of getting the best outcome of 18 points, so I will gamble and choose route R2.

Q5. Now let us take the probability of 0.45 of getting the best outcome and a probability 0.55 of getting the worst outcome from route R2. Which route do you now prefer?

Ans. I am an aversion man, but putting P= 0.45 makes the thing difficult to choose for me, but I believe I will go for the certain outcome route R1.

Q6. Can you do some more of these trials and errors in your mind and tell me what is the value of the probability (P) you would assign for the best outcome to make you indifferent between the two routes R1 and R2?

Ans. I would guess that a probability of 0.5 will make me indifferent between the two routs R1 and R2.

Q7. That is good. According to utility theory, by choosing the probability that makes you indifferent between the two routes you have assigned a utility value for the certain outcome of 13 points.

Ans. How can you explain to me please?

Rep. In fact this what I am looking for *ie* I want to know the probability that makes you indifferent between the lotteries R1 and R2. In this case I can tell you the utility value of your certain outcome.

It is known from the principals of probabilities that the expected value of any random variable in the space will equal the sum of probability of each variable times its score. In this case the expected utility for the route R2 which includes two variables or two outcomes (the best outcome with $u = 1$ and the worst outcome with $u = 0$) will be:

$0.5 \text{ X } 1 + (1 - 0.5) \times 0 = 0.5$

So the utility value of route R2= 0.5 Since you are indifferent between the two routes at a probability P = 0.5, according to the utility theory, the two routes will have the same utility value. In this case the utility value of R1, which represents a certain outcome of a 13 point score, is equal to the utility of R2 which is equal 0.5. From this we achieve an excellent result by finding the U (13 points) = 0.5.

Following the same procedure, the utility values for the other scores were obtained and these are presented in Table A2, from these values a utility function for the decision-maker for this criterion was constructed as shown in Fig A2.

This procedure was then applied for every criterion, bearing in mind the questions are not necessarily the same for each criterion *ie* after a decision-maker become familiar with the principal, a straight forward probability that makes the decision-maker indifferent between the two routes or lotteries.

Contractor	A	B	C	D	E
Plant and equipment score (points)	13	14	10	18	16
Utility values	0.5	0.7	0	1	0.9

Table A2: Utility values of the five bidders in criterion {10}

CAPTIONS

Fig	**Caption**
1	*Increasing Utility function*
2	*Types of decision makers*
3	*Profile of the average scores for the five bidders A,B,C, D and E*
4	*Scaling constants in a hierarchical structure*
5	*Pair of lotteries for criterion {10} plant and equipment*
6	*Utility curve for criterion {10} plant and equipment*

Table	**Caption**
1	*Bid amounts of the five bidders*
2	*Main criteria and sub-criteria for the case study*
3	*Scores of the five bidders for the complete set of criteria*
4	*Average scores of the five bidders for the main criteria*
5	*Weights of the main criteria of the case study*
6	*Relative weights of the sub-criteria for the case study*
7	*Bidders' scores for* ***Criterion {10} Plant and equipment***
8	*Utility values for the best and worst outcomes for criterion {10}*
9	*Utility values for different scores for criterion {10}*
10	*Utility values for the five bidders as assigned by Mr Oztash*
11	*Overall utility values for Mr Oztash*
12	*Overall utility and ranking of the five bidders from four decision-makers*

Contractor	A	B	C	D	E
Advance payment (million £)	0.1	0.3	0.3	0.3	0.1
Capital bid (million £)	3.9	3.5	3.5	4	3.6
Routine maintenance (£m)	0.3	0.25	0.3	0.25	0.1
Major repairs (million £)	0.4	0.35	0.2	0.4	0.4
Total bid price (million £)	**4.7**	**4.4**	**4.3**	**4.8**	**4.2**

Table 1: Bids amounts of the five bidders

(1) Bid amount				(2) Financial soundness			
Advance payment	Capital bid	Routine maintenance	Major repairs	Financial stability	Credit rating	Bank arrangements and bonding	Financial status
(3) Technical ability				**(4) Management capability**			
Experience	Plant and equipment	Personnel	Ability	Past performance and quality	Project management organisation	Experience of technical personnel	Managemen t knowledge
(5) Health and safety records				**(6) Reputation**			
Safety	Experience modification rate	Occupational safety OSHA	Manageme nt safety accountabili ty	Past failures	Length of time in business	Past client/contractor relationship	Other relations

Table 2: Main criteria and their sub-criteria for the case study

Contractor	A	B	C	D	E
{1} Advance payment(£m)	0.1	0.3	0.3	0.15	0.1
{2} Capital bid (m £)	3.9	3.5	3.5	4	3.6
{3} Routine maintenance(m£)	0.3	0.25	0.3	0.25	0.1
{4} Major repairs (m£)	0.4	0.35	0.2	0.4	0.4
{5} Financial stability (points)	12	11	13	10	10
{6} Credit rating (points)	14	15	14	9	11
{7} Bank arrangements (pts)	15	13	15	10	13
{8} Financial status (pts)	17	17	16	11	14
{9} Experience (points)	11	15	9	16	6
{10} Plant and equipment	13	14	10	18	16
{11} Personnel (points)	9	14	14	15	6
{12} Ability (points)	11	11	15	13	6
{13} Past performance (pts)	15	10	16	10	10
{14} Management organisation	10	17	13	10	11
{15} Experience of technical personnel (points)	12	16	11	9	14
{16} Management Knowledge	15	15	14	19	15
{17} Safety (points)	9	17	16	10	17
{18} EMR (points)	15	8	17	6	20
{19} OSHA (points)	8	13	9	10	16
{20} Management safety accountability (points)	7	11	12	8	11
{21} Past failures (points)	15	16	11	10	11
{22} Length of time in business	14	15	14	11	6
{23} Client/contractors relationship (points)	10	13	14	10	10
{24} Other relationships	9	12	17	9	13

Table 3: Scores of the five bidders for the complete set of criteria

Contractor	A	B	C	D	E
(1) Bid amount (Million £)	4.7	4.4	4.3	4.8	4.2
(2) Financial capacity	14.5	14.5	14.5	10	12
(3) Technical ability	11	12	12	15.5	8.5
(4) Managerial capability	13	13.5	13.5	12	12.5
(5) Health and safety	10	13	13	8.5	16
(6) Reputation (Points)	12	14	14	10	10

Table 4: Average scores of the five bidders for the main criteria

Criteria	Bid amount	Financial soundness	Technical ability	Management capability	Healthand safety	Reputation
Weight	0.55	0.15	0.1	0.1	0.05	0.05

Table 5: Weights of the main criteria of the case study

(1) Bid amount (0.55)				(2) Financial soundness (0.15)			
Advance payment	Capital bid	Routine maintenance	Major repairs	Financial stability	Credit rating	Bank arrangements and bonding	Financial status
.05	.75	.1	.1	.3	.2	.15	.35
(3) Technical ability (0.1)				**(4) Management capability (0.1)**			
Experience	Plant and equipment	Personnel	Ability	Past performance and quality	Project management organisation	Experience of technical personnel	Mngement knoledge
.2	.45	.3	.05	.4	.2	.2	.2
(5) Safety record (0.05)				**(6) Reputation (0.05)**			
Safety	Experience modification rate	Occupational safety OSHA	Management safety accountability	Past failures	Length of time in business	Past client/contrctor relationship	Other relations
.2	.3	.3	.2	.3	.1	.4	.2

Table 6: Relative weights of subcriteria for the case study

Contractor	A	B	C	D	E
Plant and equipment scores (points)	13	14	10	18	16

Table 7: Bidders' scores for ***Criterion {10} Plant and equipment***

Contractor	D	C
Plant and equipment score (points)	18	10
Utility value	1	0

Table 8: Utility values for the best and worst outcomes for the criterion {10}

Contractor	A	B	C	D	E
Score (points)	13	14	10	18	16
Utility value	0.5	0.7	0	1	0.9

Table 9: Utility values for different scores for criterion {10}

Contractor	A	B	C	D	E
{1}. Advance payment	1	0	0	0.8	1
{2}. Capital bid	0.55	1	1	0	0.85
{3}. Routine maintenance	0	0.85	0	0.85	1
{4}. Major repairs	0	0.8	1	0	0
{5}. Financial stability	0.9	0.85	1	0	0
{6}. Credit rating	0.95	1	0.95	0	0.70
{7}. Bank arrangements	1	0.85	1	0	0.85
{8}. Financial status	1	1	0.95	0	0.55
{9}. Experience	0.85	0.95	0.6	1	0
{10}. Plant and equipment	0.5	0.7	0	1	0.9
{11}. Personnel	0.7	0.95	0.95	1	0
{12}. Ability	0.85	0.85	1	0.95	0
{13}. Past performance	0.95	0	1	0	0
{14}. Management organisation	0	1	0.85	0	0.7
{15}. Experience of technical personnel	0.80	1	0.70	0	0.90
{16}. Management Knowledge	0.5	0.5	0	1	0.5
{17}. Safety	0	1	0.95	0.5	1
{18}. EMR	0.85	0.4	0.95	0	1
{19}. OSHA	0	0.7	0.5	0.6	1
{20}. Management safety accountability	0	0.90	1	0.5	0.90
{21}. Past failures	0.90	1	0.50	0	0.5
{22}. Length of time in business	0.95	1	0.95	0.75	0
{23}. Past client/contractors relationship	0	0.90	1	0	0
{24}. Other relationships	0	0.70	1	0	0.75

Table 10: Utility values for the five bidders as assigned by Mr Oztash

Contractor	A	B	C	D	E
{1}. Advance payment	1 x 0.0275	0 x 0.0275	0 x 0.0275	0.8x0.0275	1 x 0.0275
{2}. Capital bid	0.55x 0.4125	1 x 0.4125	1 x 0.4125	0 x 0.4125	0.85 x 0.4125
{3}. Routine maintenance	0 x 0.055	0.85 x 0.055	0 x 0.055	.85x 0.055	1 x 0.055
{4}. Major repairs	0 x 0.055	0.8 x 0.055	1 x 0.055	0 x 0.055	0 x 0.055
{5}. Financial stability	0.9 x 0.045	0.85 x 0.045	1 x 0.045	0 x 0.045	0 x 0.045
{6}. Credit rating	0.95 x 0.03	1 x 0.03	0.95x 0.03	0 x 0.03	0.7 x 0.03
{7}. Bank arrangements	1 x 0.0225	0.85x 0.0225	1 x 0.0225	0 x 0.0225	0.85 x 0.0225
{8}. Financial status	1 x 0.0525	1 x 0.0525	.95x 0.0525	0 x 0.0525	0.55 x 0.0525
{9}. Experience	0.85 x 0.02	0.95 x 0.02	0.6 x 0.02	1 x 0.02	0 x 0.02
{10}. Plant and equipment	0.5 x 0.045	0.7 x 0.045	0 x 0.045	1 x 0.045	0.9 x 0.045
{11}. Personnel	0.7 x 0.03	0.95 x 0.03	0.95 x 0.03	1 x 0.03	0 x 0.03
{12}. Ability	0.85 x 0.005	0.85 x 0.005	1 x 0.005	0.95x 0.005	0 x 0.005
{13}. Past performance	0.95 x 0.04	0 x 0.04	1 x 0.04	0 x 0.04	0 x 0.04
{14}. Mngmnt organisation	0 x 0.02	1 x 0.02	0.85 x 0.02	0 x 0.02	0.7 x 0.02
{15}. Experience of technical personnel	0.8 x 0.02	1 x 0.02	0.7 x 0.02	0 x 0.02	0.90 x 0.02
{16}. Management Knowledge	0.5 x 0.02	0.5 x 0.02	0 x 0.02	1 x 0.02	0.5 x 0.02
{17}. Safety	0 x 0.01	1 x 0.01	0.95 x 0.01	0.5 x 0.01	1 x 0.01
{18}. EMR	0.85 x 0.015	0.4 x 0.015	0.95x 0.015	0 x 0.015	1 x 0.015
{19}. OSHA	0 x 0.015	0.7 x 0.015	0.5 x 0.015	0.6 x 0.015	1 x 0.015
{20}. Management safety accountability	0 x 0.01	0.90 x 0.01	1 x 0.01	0.5 x 0.01	0.9 x 0.01
{21}. Past failures	0.9 x 0.015	1 x 0.015	0.5 x 0.015	0 x 0.015	0.5 x 0.015
{22}. Length of time in business	0.95 x 0.005	1 x 0.005	0.95x 0.005	0.75x 0.005	0 x 0.005
{23}. Client/contractors relationship	0 x 0.02	0.9 x 0.02	1 x 0.02	0 x 0.02	0 x 0.02
{24}. Other relationships	0 x 0.01	0.70 x 0.01	1 x 0.01	0 x 0.01	0.75 x 0.01
OVERALL UTILITY	**0.558**	**0.857**	**0.814**	**0.211**	**0.648**

Table 11: Overall utility values for Mr Oztash

Interviewee Contractor	A	B	C	D	E
Oztash	0.558	0.857	0.814	0.211	0.648
Ahmet	0.522	0.815	0.783	0.191	0.633
Hussin	0.516	0.792	0.792	0.177	0.673
Kamalain	0.511	0.761	0.758	0.175	0.653
Rank order	**4**	**1**	**2**	**5**	**3**

Table 12: Overall utility and ranking of the five bidders from four decision makers