A Stochastic Cost Engineering System (SCENS) Applied to Estimating and Tendering for Bill of Quantities Contracts

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Abstract

Contracts based on bill of quantities are very common in construction industry in many Arab countries as well as other countries all over the world. Although estimating and tendering are overwhelmed by uncertainties, the common practice is still dominated by the deterministic approaches. A stochastic cost engineering system for estimating and tendering for measured construction projects is described in some details. It is preceded by an overall description of project estimating and tendering environment which emphasises the importance of the system. A brief description of the system objectives is stated. Sample project files are given for illustration. The system is implemented in the *Windows* environment using the *Microsoft Excel* spreadsheet. Discussion of the system is followed by statement of the important conclusions.

Introduction

Bill of Quantities (B/Q), since its evolution, has become a vital component of contract documents in construction industry. The measurement contract based on a bill of quantities is the most common type of contract in use in Arab countries. It has

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a similar popularity in the UK and many other countries all over the world (Banjoko 1985; McCaffer and Baldwin 1991). B/Q is a list of items giving brief identifying description and estimated quantities of the work comprised in a contract (Institution of Civil Engineers 1985). In the UK practice and the like it is usually prepared by the quantity surveyor or the consultant (architect/engineer) according to a certain standard method of measurement such as UK Civil Engineering Standard Method of Measurement (CESMM). In competitive tendering, all tenderers (contractors) are required to fill in the unit rate column for all B/Q items that eventually result in the tender amount of the project (Table 1). The contractor whose tender amount is the lowest is often awarded the contract. In each tender the contractor faces the dilemma of having his/her tender amount low enough to get the job and at the same time maintaining it high enough to yield a satisfactory profit. What makes the situation even more difficult is that s/he is not quite sure how much it will cost in the first place. In spite of the plain fact that uncertainties overshadow the estimating and tendering procedures, the common practice in construction industry is still dominated by the deterministic approaches.

Problem Background

The tendering period may be the most prominent period in the life cycle of any construction project. For the contractor, it is indeed the most important period. The contractor has to achieve many important tasks and take serious decisions within a limited time and a competitive atmosphere. In the measurement contract with quantities the contractor usually receives the tendering documents which include the bill of quantities, the drawings, the conditions of contract and the specifications. Within a few weeks (may be three or four) the contractor has to price fully the bill of quantities and submit the tender. The following are the main tasks, with price implications, which the contractor has to perform:

1. To study the drawings, specification and the B/Q to comprehend the project and grasp what has to be done.

2. To extract materials lists out of the B/Q and specifications and ask for quotes from suppliers.

3. To make a general construction plan for the project and decide the construction methods, construction sequence and resource needs and allocation.

4. To make the necessary contacts to get information related to labour and plant costs.

5. To decide what parts of the work to subcontract and ask for quotations.

6. To study the conditions of contract to understand the legal obligations and estimate the corresponding cost consequences.

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7. To estimate the indirect (overheads and mark-up) costs of the project.

8. To prepare the costs of all items in a unit rate form which covers direct and indirect charges.

Table 1. Example project B/Q

Number	Item Description	Unit	Quantity	Rate	Amount
E210	Excavation for cuttings, topsoil.	m3	4200	£0.38	£1,596.00
E624	Filling Embankments select. excavated material.	m3	6000	£0.24	£1,440.00
F153	Provision of ordinary concrete.	m3	1600	£60.00	£96,000.00
F 534	Place RC exc. 500 mm suspended slab.	m3	760	£12.00	£9,120.00
F554	Place RC colunns X-section. area: 0.25 - 1 m2.	m3	430	£17.00	£7,310.00
F564	Place RC beams X-sectional area: 0.25 - 1 m2.	m3	126	£17.00	£2,142.00
G112	Formwork rough finish horiz. width 0.1 - 0.2 m.	m	240	£5.50	£1,320.00
G145	Formwork rough finish vertical.	m2	145	£32.00	£4,640.00
G511	6 mm diameter reinforcement mild steel bars.	t	15.5	£814.00	£12,617.00
G514	12 mm diameter reinforcement mild steel bars.	t	32	£780.00	£24,960.00
U333	450 mm nominal thickness straight brickwall.	m2	640	£80.00	£51,200.00
U511	Vertical 140 mm nominal thickness blockwall.	m2	710	£18.00	£12,780.00
V113	Zink rich primer paint on metal surfaces.	m2	480	£2.80	£1,344.00
V313	Oil paint in three coats on metal surfaces.	m2	480	£4.20	£2,016.00
V533	Emulsion paint on smooth conc. surfaces.	m2	580	£2.60	£1,508.00
	TOTAL				**£229,993.00**

These tasks need tremendous efforts to complete, especially when B/Q contains thousands of items. As the resources are limited, it is important that efforts be employed effectively. There are thousands of factors to be estimated in order to reach the final tender amount. Of course some of these factors are more important than others. So, arrangement of priorities is very crucial to get the most accurate charge estimate within the time available. The optimal estimate, that the contractor is after, is the one which is reasonably profitable and highly competitive at the same time.

For this type of contract, the contractors need to have the estimating database in the item unit rate format in order to be ready for filling in the B/Q. Historical data of the item unit rates for previous projects would obviously be helpful in building realistic probability distributions for these unit rates.

System Objectives

The objective of the work reported here is to develop a contractor's cost engineering system designed for estimating and tendering so as:

1) to persuade the contractor to adopt the stochastic approach so that s/he will be in tune with the very nature of the tendering situation.

2) to relieve the contractor of the strain related to time limit by utilising the fast computer capabilities of crunching numbers.

3) to highlight the cost significant items of the B/Q to draw the contractor's attention, so that s/he can use her/his effort and expertise more effectively.

System Implementation

The overall structure of the Stochastic Cost ENgineering System (SCENS) and its interactions are shown in Figure1. For the estimating module, the initial input is the unpriced B/Q and the ultimate output is the priced B/Q ready for submission in the tender. There are close interactions between SCENS, the User and the Database which contains the corresponding probabilistic unit rates with different degrees of sophistication and to different levels of detailing.
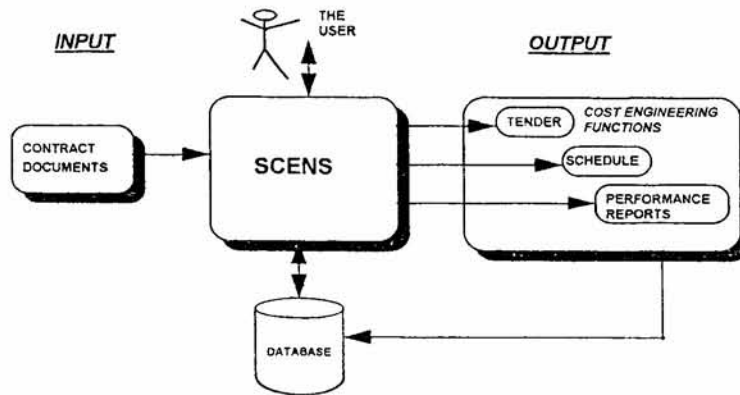

Figure 1. Overall Structure of the System

The implementation of the system has been done mainly in two stages. In the **first stage**, as is shown in Figure 2, the system puts the original B/Q into a predefined file template and gives it the name of BQAE (similar to the example project B/Q shown in Table 1 but with blank Rate and Amount columns) (Barnes 1986). Out of the many data files of different degrees of sophistication and detailing stored in the Database, the system picks the appropriate database source (file) DBLEV as designated by the user. The next step is to filter DBLEV into DBSEL which includes only the items listed in BQAE. Ideally, opposite to each item in DBSEL there should be different unit rate values corresponding to different cumulative probability percentages (e.g. 100, 0, 75, 25 and 50) denoted by PR100, PR0, PR75, PR25 and PR50 respectively (see Table 2) (Kiangi 1988). In addition all template files have, by default, provisions for the 100%, 0% and 50% which stand, respectively, for the two limits of the cumulative probability distribution and the point in the middle.
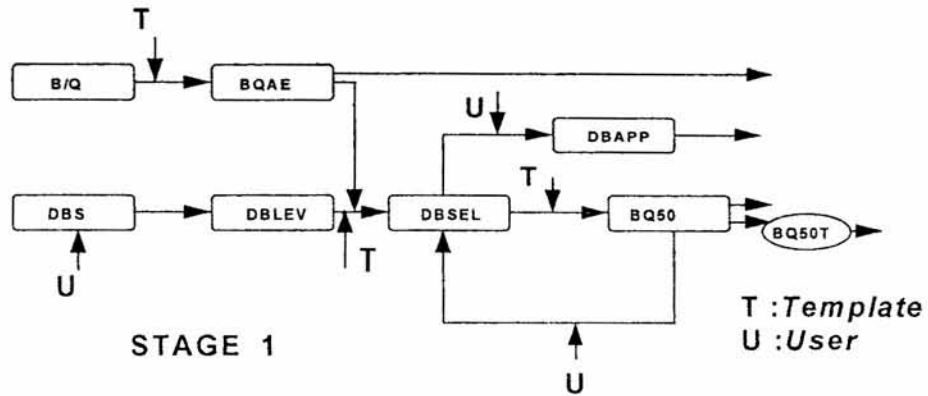
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Figure 2. Flow Chart for Stage 1 for SCENS's Estimating Module

In the following step the system dumps the BQAE file into BQ50 template file which consequently imports the whole "field" of 50% cumulative probability (PR50) and gets the project cost amount calculated on this basis which is denoted here as BQ50T. In BQ50, the items are also sorted in the descending order according to their amount, to draw the attention of the contractor to the cost significant items. At this point the user is expected to review the data available in DBSEL beginning with these items. After refinement, if any, The reviewed DBSEL is named DBAPP. The rate probability values in DBAPP represent continuous functions.
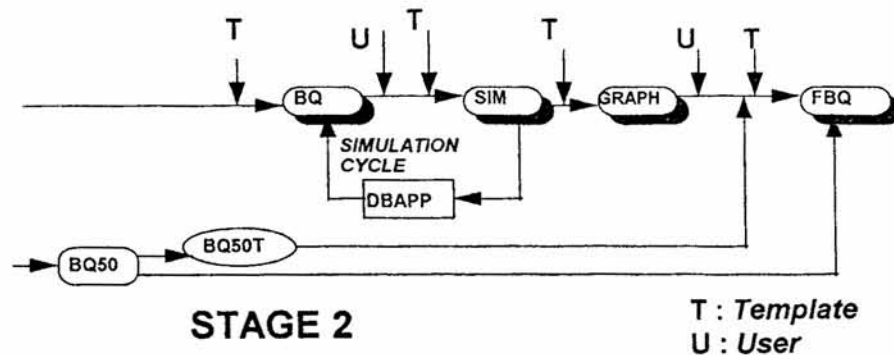

Figure 3. Flow Chart for Stage 2 for SCENS's Estimating Module

Once the user decides that the data is satisfactory the **second stage** may start (see Figure 3). In this stage the **Monte Carlo Simulation** technique is used to pick a rate value for each item and get a simulated project cost. By repeating this process many times a probability distribution of the project cost is produced (Singh 1987).

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The user can choose the number of simulations to suit his/her requirements. Subsequently the system opens a template file BQ that is apparently similar to BQ50 but it is different in terms of picking different unit rate values that are calculated according to a Monte Carlo simulation-based function. The unit rate values corresponding to the cumulative probability percentages are the arguments of this function. For items whose rate probability distribution is not available the function picks the values corresponding to the 50% cumulative probability. In each simulation cycle, new random numbers are generated and new corresponding project cost amount is transferred to SIM file. Eventually SIM file includes as many project cost amounts as the number of simulations chosen by the user. These amounts are sorted and displayed in a graph (Figure 4) showing full cumulative occurrence distribution which is assumed to represent the cumulative probability distribution of project cost.

In light of the simulated probability distribution, the risk attitude of the contractor, the tendering situation and other related factors, the user has to arrive at a 'basic' project cost. S/he then adds a mark-up to this 'basic' cost to arrive at the adopted tender amount. This amount is divided by BQ50T to get a factor by which each unit rate of BQ50 is multiplied. The resulting file is named FBQ which represents the priced B/Q for submission with the tender. Alternatively, the overheads could be included in the simulation cycles (BQ and SIM files) by itemising the overhead elements and adding them at the bottom of the B/Q. Consequently, DBSEL should contain these overhead elements and their corresponding cumulative probability percentages, so that the user can decide directly the tender amount.

Discussion

The items are recognised by the computer by their corresponding item numbers. So, these numbers should be uniquely coded. Fortunately the new versions of the standard method of measurements in the two sectors of construction industry in the UK, civil engineering and building, satisfy this requirement (McCaffer and Baldwin 1991).

As historical data for many item rates is not available; the sequence of the cumulative probability percentages chosen is 100%, 0%, 75%, 25%, and 50%, to help the user estimate the corresponding values for these percentages more rationally, with least cognitive and emotive biases.

Besides the probability distribution pattern shown in the example, the system includes other patterns as well. These include the pattern of (100%, 0%, 90%, 10% and 50%) and (100%, 0%, 90%, 10%, 70%, 30% and 50%).

A complete set of equivalent template files accompanies each probability distribution pattern. More sophisticated patterns are not practical for construction projects, but any other pattern could be easily added to the system.

Table 2. Typical Database File (DBSEL)

Number	Item Description	Unit	PR100	PR0	PR75	PR25	PR50
E210	Excavation for cuttings; topsoil.	m3	£0.29	£0.50	£0.32	£0.41	£0.38
E624	Filling Embankments select. excavated material.	m3	£0.19	£0.30	£0.21	£0.26	£0.24
F153	Provision of ordinary concrete.	m3	£58.56	£61.92	£59.04	£60.48	£60.00
F 534	Place RC exc. 500 mm suspended slab.	m3	£9.42	£15.45	£10.28	£12.86	£12.00
F554	Place RC columns X-section. area: 0.25 - 1 m2.	m3	£16.06	£18.26	£16.37	£17.31	£17.00
F564	Place RC beams X-sectional area: 0.25 - 1 m2.	m3	£13.66	£21.45	£14.77	£18.11	£17.00
G112	Formwork rough finish horiz. wid. 0.1 - 0.2 m.	m	£4.95	£6.24	£5.13	£5.68	£5.50
G145	Formwork rough finish vertical.	m2	£28.00	£37.34	£29.33	£33.33	£32.00
G511	6 mm diameter reinforcement mild steel bars.	t	£698.87	£967.51	£737.25	£852.38	£814.00
G514	12 mm diameter reinforcement mild steel bars.	t	£669.97	£926.71	£706.65	£816.68	£780.00
U333	450 mm nominal thickness straight brickwall.	m2	£68.01	£95.98	£72.01	£84.00	£80.00
U511	Vertical 140 mm nominal thicknee blockwall.	m2	£13.94	• £23.42	£15.29	£19.35	£18.00
V113	Zink rich primer paint on metal surfaces.	m2	£1.99	£3.89	£2.26	£3.07	£2.80
V313	Oil paint in three coats on metal surfaces.	m2	£3.61	£4.98	£3.81	£4.40	£4.20
V533	Emulsion paint on smooth conc. surfaces.	m2	£2.23	£3.09	£2.35	£2.72	£2.60

The system can handle another dimension of sophistication. It has the flexibility to deal with the probability distribution of values at the level of item rate components. This means to have, for instance, probability distribution pattern for materials, plant and labour costs for each item. Hence in simulation cycles, values can be picked from component levels. The system can go deeper and deeper and can deal with the probability distribution of the elements of each item component or even with factors affecting these elements. Again, going that deep in construction projects is not practical. In addition, the memory requirements and processing time increase significantly as the degree of sophistication increases.
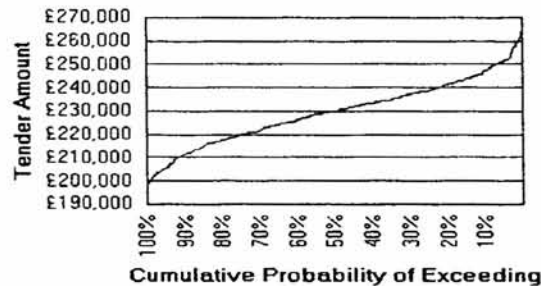

Figure 4. Project Tender Amount Probability Distribution

As SCENS is a microcomputer-based system, it should be attractive to contractors of any size. It is coded as a *Microsoft Excel* spreadsheet add-in macro. It exploits the capabilities of the user friendly *Windows* environment as well as the spreadsheet flexibility and power. This will minimise drastically the effort needed to learn the system and master it. Moreover, it gives a good opportunity to "recycle" the available resources (spreadsheet software and familiarity to use it) and reinvest them

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in a new domain. In addition, the spreadsheet structure is quite compatible with the B/Q format and with estimating and tendering practice.

Apart from the applications of the system in the other two modules, scheduling and cost control, the estimating applications can be further extended. It can be used, with few alterations, during construction for interim payment valuations. The client can use it in the design period in evaluating the design alternatives (Banjoko 1985). As the cost of alternatives will be probabilistic, the system can be applied and incorporated with the value engineering technique used in the evaluation process. The client may also use the system to obtain a more accurate estimation for the project cost with an early warning of potential overrun.

Conclusions

- Contract estimating and tendering is a venture and therefore an ability to assess its risk should be an important part of the decision making process.

- It has been shown that a very practical and stochastic system can be set up using an industry standard spreadsheet package, *Excel*, to obtain the venture profile in the form of a simulated cost probability distribution.

- The availability of the venture profile allows the contractor to take into account her/his attitude to risk in arriving at the tendering amount.

- The employment of the principle of cost-significance is essential to produce an effective estimating and tendering system. It also helps in building up a complete stochastic database gradually.

Acknowledgement

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