PROCEEDINGS PAPER 45, 993-999 2016

ERRORS IN BILL OF QUANTITY IN PUBLIC PROCUREMENT: HOW TO IMPROVE ACCOUNTABILITY AND ACCURACY

Saïd Boukendour*

INTRODUCTION

Many building and maintenance projects are procured through competitive unit-price bidding where bill of quantities is a part of tendering documents. Basically, a bill of quantities (BQ) is a listing of items of work that make up the project with detailed descriptions and estimated quantity of each work item. The BQ is prepared by quantity surveyors (QS) on the basis of detailed drawings and specifications provided by architects and designers according to a standard of measurement (Brook, 1998; RICS, 2011).

The primary purpose of the BQ is to enable contractors to prepare tenders efficiently and accurately (Seeley, 1997). Thereafter, when the contract has entered into, the BQ provides a very strong basis for the valuation of work executed and variations as well as for budgetary control and accurate cost reporting of the contract (RICS, 2011). Without a BQ there is also the risk that the successful tenderer may underestimate the quantities and then be unable to complete the work, and/or cut in corners in an attempt to recover the consequent loss (Davis & Baccarini, 2004)

Despite its many recognized benefits, the BQ may also cause various inefficiencies when the estimates are inaccurate. One of these is known as unbalanced bidding where opportunistic contractors start by reviewing the BQ looking for items they think they are under estimated in order to inflate the price of these items in

----

** Saïd Boukendour, Ph.D., is Associate Professor, Department of Administrative Sciences, University of Quebec at Outaouais, Canada. His teaching and research interests are in financial engineering, economics of contracts and incentives, derivatives and real options, project management.*

their tender, resulting in higher overall profit, even though the total amount of the bid is lower (Ellis et al., 2007)

During contract execution, the change in the final quantities in comparison to the estimate in the BQ may give rise to claims for compensation. For instance, if the estimated quantities are higher than the quantities that are actually carried out, the contractor may have a claim for uncovered overheads costs and profits (Long, 2015).

Moreover, a significant underestimate of the required quantities may create the need to apply for additional funding, which may lead to delaying the project and even changing its scope. Conversely, a significant overestimate of the required quantities implies that funding may be unnecessarily taken away from other projects.

Therefore, the accuracy of BQ estimates is of obvious importance on many respects. However, as has been observed on many occasions, those who practice estimating seem to be the least concerned. (Fortune, 2006; Cheung, Wong, & Skitmore, 2008). Indeed, the QSs do not guarantee the accuracy of their estimates. Like architects, engineers or lawyers, they are only legally committed to use reasonable and ordinary care in the practice of their profession.

To contribute in solving this problem, we propose a compensation system based on the accuracy of the estimates in the best interests of the owners and the quantity surveying profession.

ERRORS MEASUREMENT AND PARETO DISTRIBUTION

Most forecast error measures can be divided into two groups: standard and relative error measures. Standard error measures typically provide the error in the same unit as the data, which makes it difficult to compare accuracies across different scales or units of measures. Relative measures, which are unit-free, can significantly better to use because they provide an easier understanding of the quality of the forecast (Sanders, 1997).

Thus, the estimation accuracy of a given item can be measured using the ratio:

$$\frac{Actual - Estimate}{Estimate}$$

However, such measure has the problem of errors of opposite signs cancelling themselves out when added. Instead, absolute values can be used; with the assumption that the cost or the disutility of over-estimating is the same as that of under-estimating. For instance, if the estimate is 100 units, the relative error of the estimate will be of 0.2 or 20% either the actual quantity is 80 units or 120 units.

$$\left|\frac{Actual - Estimate}{Estimate}\right|$$

One can also measure the estimation errors using the ratio:

$$\frac{Actual}{Estimate} = 1 + \left|\frac{Actual - Estimate}{Estimate}\right|$$

Hence, we can compute the mean of relative absolute errors for the entire project (BQ) as follows:

$$\mathrm{X} = 1 + \frac{1}{n}\sum_{k=0}^{n} |(A_i - E_i)/E_i|$$

Where , A_i and E_i stand for actual quantity and estimated quantity for item i respectively. They can also stand for actual and estimated unit-price for item i.

If we consider a very large number of BQ produced by a QS, X becomes a random variable that follows Pareto distribution.

$$P(X > x) = X^{-a},\ X \geq 1; a \geq 0$$

Where a is the shape parameter (tail index). The greater the parameter a, the more accurate are the estimates.

The expected value of X is:

$$E(X) = \frac{a}{a-1}, \qquad X > 1$$

MENU OF ACCURACY-BASED FEES

The incentive formula that we suggest below applies to any form of remuneration: time charge, or fixed fee, or percentage fee. Basically, it adjusts the fee as a function of the accuracy as follows:

$$F = cX^{-a}$$

Let take for example a fee c= $200 per hour, Table 1 gives the hourly rate as a function of X, and a varying from 0 to 3.

TABLE 1
Fee per Hour as a Function of X and a

a	0	1	2	3
1	$200.00	$200.00	$200.00	$200.00
1.05	$200.00	$190.48	$181.41	$172.77
1.10	$200.00	$181.41	$165.29	$150.26
1.15	$200.00	$173.91	$151.23	$131.50
1.20	$200.00	$166.67	$138.89	$115.74

It shows that for a = 0, the hourly rate remains equal to $ 200 regardless of the precision of the estimate, which is consistent with the current practice. For all the other values of a, the hourly rate decreases when X (the inaccuracy) increases. And it does it more downward when a increases.

If the QSs were asked to choose their fee scale, all they would pick a = 0, which allows them to obtain the highest remuneration regardless the accuracy of their estimate. Therefore, this menu of fees does not satisfy the incentive compatibility constraint. A menu of contracts is called incentive-compatible if it is designed in such a way that each agent picks the contract that best matches his or her type (Myerson, 1979; Lafont & Martimort, 2002).

To make the menu of fees incentive-compatible, we first determine for each parameter $a > 1$ its corresponding value of c (hourly rate) such that the expected values of fees are all equal, i.e.:

$$c_2 \times \frac{2}{2-1} = c_3 \times \frac{3}{3-1} = c_4 \times \frac{4}{4-1} = \cdots . = c_k \times \frac{k}{k-1}$$

Hence:

$$\frac{3}{2}c_3 = 2c_2 \Rightarrow c_3 = \frac{4}{3}c_2$$

$$\frac{4}{3}c_4 = 2c_2 \Rightarrow c_4 = \frac{3}{2}c_2$$

$$\frac{5}{4}c_5 = 2c_2 \Rightarrow c_5 = \frac{8}{5}c_2$$

For example, if $c_2 = \$150$, we have : $c_3 = \$200$, $c_4 = \$225$, $c_5 = \$240$ (Table 2).

TABLE 2
Menu of Incentive-Compatible Fees

	2	3	4	5
1	\$150.00	\$200.00	\$225	\$240.00
1.1	\$123.97	\$150.26	\$153.68	\$149.02
1.2	\$104.17	\$115.74	\$108.51	\$96.45
1.3	\$88.76	\$91.03	\$78.78	\$64.64
1.4	\$76.53	\$72.89	\$58.57	\$44.62

The QS who is able to produce more accurate estimates will choose the parameter a higher than that of who are less capable. For instance, one who feels able to provide an estimate within a 10% range of accuracy will select the fees with a = 4. One who is not able to do so is better of choosing a lesser value of a.

The owner offers this menu of accuracy-based fees, and selects among the QSs the one that picks the highest value of a. But, if it proves that the so selected QS is not as able as he alleges, he will be sanctioned by being compensated at a lower rate than that he would have obtained if he had told the truth. This ensures to the principal to select the most competent QS, and anyway, to pay for the accuracy he gets at the best market price.

CONCLUSION

Though it is widely recognized that any estimate have an inherent inaccuracy level, it also largely dependent upon the QS's professional skills and judgement and the quality of information available. Many studies found that surveying firms do not monitor their performance, and they have no systematic feedback mechanisms that provide information on the accuracy of their previous estimates enabling them to improve their estimating methods and processes. But if they were fairly compensated for the accuracy of their estimate, they would be better incentivized for investing in the improvement of their skills, and their systems and working methods, which is beneficial for all the project partners.

Nowadays, most professions including the QSs are experiencing a crisis of public confidence because, we believe, the trust on which their services are built is only presumed in law and ethical codes, but not clearly proven in practice. Trust is best guaranteed when interests of the parties are aligned. The alignment of interests does not mean that the professionals are owed to bear all the consequences of their errors but only that they have sufficient interests at stake to work harder and better towards the achievement of the common objective.

REFERENCES

Brook, M. (1998). *Estimating and Tendering for Construction Work.* Oxford, UK: Butterwork-Heinemann.

Cheung, F.K.T., Wong, M.W.L., & Skitmore, M. (2008, April). "A Study of Clients' and Estimators' Tolerance towards Estimating Errors." *Construction Management and Economics*, *26*: 349-362.

Davis, P.R., & Baccarini, D. (2004). "The Use of Bills of Quantities in Construction Projects – An Australian Survey." In Ellis, R. & Bell, Malcolm (Eds.), *Proceedings of the COBRA* 2004 International Construction Research Conference of the Royal Institution of Chartered Surveyors, 7-8 September, Leeds Metropolitan University, Leeds: RICS Foundation.

Ellis, R., Pyeon, J.H., Herbsman, Z. Minchin, E., & Molnear, K. (2007). *Evaluation of Alternative Contracting Techniques on FDOT Construction Projects*. [Online]. Available at www.dot.state.fl.us. [Retrieved, March 1, 2016].

Fortune, C. (2006). "Process Standardisation and the Impact of Professional Judgement on the Formulation of Building Project Budget Price Advice." *Construction Management and Economics*, *24*: 1091-1098.

Lafont, J.J. & Martimort, D. (2002). *The theory of Incentivess: The Principal-Agent Model*. Princeton, NJ: Princeton University Press.

Long, R.G. (2015). *Construction Claims for Variation in Quantity*. Long International, Inc. [Online]. Available at www.experts.com. [Retrieved March 30, 2016].

Myerson, R. (1979). "Incentive Compatibility and the Bargaining Problem." *Econometrica*, *47*: 61-73.

RICS New Rules of Measurement (2011). *Bill of Quantities for Works Procuremen*t. [Online}. Available at www.rics.org. [Retrieved March 15, 2016].

Sanders, N.R. (1997). "Measuring Forecast Accuracy: Some Practical Suggestions." *Production and Inventory Management,* 38(1):43-46.

Seeley, I.H. (1997)."*Quantity Surveying Practice* (2nd ed.). London, UK: Mcmillan.