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A study of clients' and estimators' tolerance towards estimating errors

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ABSTRACT

Previous research on building pretender cost estimating stresses the importance of giving accurate estimates and minimizing estimating errors. Cost models, especially those mathematical models using mean square error or the like for model training and validation, often treat positive errors (overestimates) and negative errors (underestimates) of equal magnitude the same. The implicit assumption is that the regret or disutility of positive errors (overestimates) is equal to that of negative errors (underestimates).

A survey was conducted in Hong Kong to study estimating practice and in particular, the attitude of clients and estimators towards estimating errors. This involved the use of regression analysis to model the relative disutility of underestimates (in terms of overestimates) for four different building types.

The results suggest that both clients and estimators are risk-averse - tolerating overestimates more than underestimates - and, arguably, clients are satisfied with overestimates. The study also revealed contrasting views between clients and estimators on the desired characteristics of estimates, with clients considering the ability to identify cost sensitive elements to be more important than accuracy.

Keywords: Expert judgement, cost planning, client, accuracy, disutility, survey, statistical regression

INTRODUCTION

In a recent paper, Fortune (2006) proposed a new agenda for research on process standardisation and the impact of judgemental bias in pretender estimating. His idea is to develop a process-based protocol that utilizes existing information engineering-based approaches, within which practitioners can adapt easily and achieve best practice. This involves the application of the major theories of judgemental heuristics and biases, such as framing, availability heuristics and representative heuristics (Kahneman *et al* 1982),

earlier identified to explain how practitioners might be affected by the cost advice process (Skitmore 1989, Gunner and Skitmore 1999).

Following this lead, a survey was conducted in Hong Kong to study the practice of biased estimating. The study first investigated the satisfaction levels of clients and estimators towards the quality of estimating. Then, it measured the discrepancy between the clients' and estimator's desired characteristics of good estimates. This showed that both clients and estimators are risk averse, more tolerable to overestimation than underestimation. Pairwise comparison test results revealed that they have similar tolerance in general for estimating errors for commercial and residential buildings, and for schools and industrial buildings. Finally, quadratic and cubic regression analysis were used to measure the disutility of overestimates to that of underestimates and reveal the client's relative disutility functions for four different types of building.

OVERVIEW OF COST ESTIMATING PRACTICE AND ACCURACY MEASUREMENT

The ability to provide cost advice is a major factor distinguishing quantity surveying as a professional discipline (Male 1990; Connaughton and Meikle 1991; RICS 1992). However, evidence from the UK suggests that clients are generally not satisfied with the cost advice given (Proctor *et al* 1993; Jackson 2002). In recognition of such situation, Brandon (1982) called for a paradigm shift from the conventional 'work-in-place' approach to an information- engineering- or product-led approach. Subsequent work by academics (e.g. Wilson 1982, Bowen and Edwards 1985 and Bowen *et al.* 1987) led to the development of new cost models and approaches to deal with uncertainty. However, evidence from different countries such as Nigeria (Akintoye *et al.* 1992), South Africa (Bowen and Edwards 1998) and UK (Fortune and Hinks 1998; Fortune and Cox 2005) indicate that little has changed in practice.

Bowen and Edwards (1996) found the potential communication barrier caused by different understandings of the cost messages between clients and cost consultants (e.g. the meaning of the estimating target) to be an important aspect concerning client satisfaction with cost advice given by cost consultants. In most studies, however, accuracy in terms of bias and consistency (Skitmore *et al* 1990) is considered to be the major attribute involved, with an assumed need to minimise both bias and inconsistency of estimates.

Although giving accurate estimates seems to be essential, Al-Khaldi (1990) found, in his study of the Saudi construction industry, that there is a tendency for estimators to be positively biased in practice. That is, they overestimate the actual costs involved. Further to his finding, this study sought to compare the opinions of practitioners (project facilitators, who represent client organisations on a project level, and consulting quantity surveyors, who carry out the estimating tasks) on this issue. As underestimation at tender stage (and hence cost overrun) may necessitate a project to be re-designed and re-tendered, and at worst, to be abandoned, it is argued that practitioners deliberately set their estimates higher than the market price in order to avoid this possibility.

METHODOLOGY

A questionnaire survey was undertaken to obtain the opinions of consulting quantity surveyors regularly producing cost estimates, and facilitators (mainly project managers from clients' organisations) who make planning decisions based on the cost estimates provided to them. The questionnaire was sent to the quantity surveyors or facilitators of a sample of firms in Hong Kong together with a covering letter describing the objectives of the research and requesting the questionnaire to be completed by those experienced in either giving or using cost advice.

A pilot study was conducted to remove ambiguity and ensure that the questionnaire could be completed within a reasonable time. As a result, several terms that might cause ambiguity were revised or elaborated. For example, the term 'forecast' which is specifically used to describe an estimate of a future event (Skitmore and Marston 1999, p.19) was replaced by 'estimate' – a more general term that is familiar to practitioners (see Appendix A).

A total of 233 revised forms of the questionnaire were mailed to a random sample of the targeted groups of respondents, namely estimators and clients, from lists of quantity surveyors and of real estate developers association of Hong Kong. In response, 45 out of 121 (return rate of 37.2%) were received from the former group and 33 out of 112 (return rate of 29.5%) from the latter group.

RESULTS

Survey respondents' experience

The respondents were asked to indicate their length of working experience in the area of construction or property development with the ranges of 'less than 1 year', 'in between 1 to 5 years', 'in between 5 to 10 years' and 'more than 10 years'. The corresponding percentages of respondents for the estimator's group are 11.11%, 40%, 28.89%, and 20%, and that of the client's group are 12.12%, 18.18%, 33.33%, and 36.36%.

Satisfaction level towards estimates

The respondents were asked if they were satisfied with the quality of estimates produced or received. The satisfaction levels of the respondents with different years of experience for the estimator's group and the client's group are shown in Table 1. The majority of both the clients and estimators were neutral about their satisfaction towards the cost estimates; there were more satisfied respondents than dissatisfied respondents; and no respondents expressed a strong satisfaction or dissatisfaction.

This is contrary to the previous evidence from the UK which suggests that clients are generally dissatisfied with construction cost advice. One proposition is that estimates produced in Hong Kong are more accurate than those of the UK and thus the clients were less dissatisfied. Recent empirical work on the estimating accuracy of different nations from 10 data sets however shows this not to be the case (Skitmore and Cheung 2007). An alternative view is that although estimating forms a core part of professional cost advice, the quality of estimates, usually measured in terms of estimating errors, is not the cause of client's dissatisfaction.

Table 1 further portrays how the level of self-satisfaction of estimates could differ according to experience of estimators. It appears that even though estimators with more experience may produce more accurate estimate (Skitmore 1985), their self-satisfaction is more or less the same as the junior estimators. One way analysis of variance (ANOVA) was used to test whether the mean self-satisfaction ratings amongst the four experience group are the same. Result support the null hypothesis that there is no difference amongst the mean self-satisfaction levels amongst the four experience groups ($F_{.05} - \text{statistics} = 0.167$, significance = 0.918).

According to Helson (1964), judgements about a stimulus are relative to the peripheral and previously encountered stimuli. In human psychology, there is a ubiquitous feature of a process known as adaptation. As estimators get more experience, they get used what they have performed even though their performance might have improved through the years of practice. They may have taken their improved performance for granted.

Estimating target

The purpose of estimating is to make predictions and to predict, there must be a target - a reference point to measure the performance of an estimate. The final contract sum is the ultimate amount a client would pay to a contractor and is therefore the figure the client most wants to know. However, the presence of many unforeseeable events and uncertainties during construction, e.g. variations due to design changes or contractual claims by the contractor, makes the estimation of the final contract sum during the design and tendering stage impracticable. The majority of academics (e.g. Ogunlana and Thorpe 1987; Skitmore and Patchell 1990; Morrison 1994) use the lowest returned tender price as the estimating target. They hold the view that the primary objective of a price model is to estimate the market price which is “the (unknown) value of the contract to contractors buying on the contract market” (Skitmore and Marston 1999 p.20). McCaffer (1976), however, suggested employing the mean of the returned tender prices instead. His argument was that the mean is less variable, and is therefore more likely to be more accurate.

Respondents were asked to choose amongst the ‘lowest tender sum’, ‘second lowest tender sum’, ‘third lowest tender sum’, ‘mean tender sum’, ‘final contract sum’ or ‘don’t know’ in which an estimate is to predict. The preference of estimating targets of the estimators’ group and the clients’ group are shown in Figure 1. If the major interest of the estimating exercise is to predict the probable market price as main stream academics suggested, majority of respondents shall choose to use the lowest tender price. Surprisingly, the results revealed no single dominating estimating target. Only a few respondents considered the lowest tender as the estimating target. This clearly indicates an attempt to avoid underestimation. There are more estimators favour the use of mean returned tender sum which they may agree with McCaffer’s argument. However, the use of the third lowest returned tender prices (clients’ favourite) is ill defined. Such an aspect requires future investigation.

It is obvious, therefore, that the majority chose not to adopt the lowest tender price, presumably the market price, for prediction because they are risk-averse and wanted to

avoid the occurrence of underestimation even though this may be against the will of the investors, financial controllers or stakeholders of developers who would prefer to plan their expenditure accurately.

Assessment criteria of estimates

Five potentially desirable aspects of estimates were suggested arbitrarily for respondents to rate on a scale of 0 to 5 according to their importance. The attributes are (A) able to identify cost sensitive elements, (B) fall within expectation so that expected profit can be achieved, (C) traceable, show the cost build-up clearly, (D) close to the final contract sum, (E) close to the lowest tender sum. Respondents were allowed to specify other attributes although none of them were recorded. The average scores for quality attributes of estimates given from the estimators' group and the clients' group are shown in Figure 2. The average rates for each individual attribute from the two groups were further tested to see if they are significantly different using the t-test at the 5% level. The average rates for A ($t=13.425$, $p=0.000$) and E ($t=-8.365$, $p=0.000$) were found to be significantly different indicating a fundamental difference between clients and estimators on the importance of core quality attributes. While estimators rated accurate prediction as the most essential attribute, clients did not consider it as their primary concern. Instead, their focus was more on cost sensitive elements - probably because they provide better cost planning and control. That the estimator group rated attribute A very low suggests they may not be fully aware of the clients' real concerns.

Occurrence of underestimates and overestimates

The respondents were also asked to indicate the extent to which they had experienced underestimates and overestimates. As Figure 3 shows, nearly all the respondents reported an overwhelming occurrence of overestimates. Previous empirical evidence by Skitmore and Cheung (2007) also suggests an asymmetrical distribution between underestimates and overestimates but not as extreme as found here.

To examine the relationship between the level of satisfaction and the ratio of underestimates' to overestimates', the data are cross tabulated in Table 2. The average score trend again supports the proposition that the practitioners are more tolerable to overestimates. Moreover, a paradox of estimating is revealed; i.e., the more overestimates experienced by the respondents, the higher is the respondents' satisfaction.

It is likely, however, that this situation will be limited to an acceptable range of overestimation as unrealistically high estimates would certainly damage the estimators' goodwill and make planning very ineffective.

Acceptable range of estimates

Respondents were asked to state their acceptable range of estimates in terms of the maximum positive and maximum negative errors expressed in percentage difference to the accurate estimate for four types of building projects, namely school, commercial, residential and industrial, under good, moderate and bad market conditions. For the sake of comparing the magnitude of acceptable errors, the absolute values of negative errors for underestimates were taken.

Table 3 shows the mean absolute acceptable errors from the reference groups of organisation type and experience. The mean absolute acceptable errors of the two references groups were analysed using t-tests and one-way analysis of variance (ANOVA) tests to reveal if they are different under various subgroups of building types, error types (i.e. overestimates or underestimates), and market conditions. Since the chance of incorrectly rejecting the null hypothesis in ANOVA is greater when the error variances of the reference group samples are heterogeneous, Levene statistics were first used to test the errors' homogeneity of variances. In the presence of variance inequality, Kruskal Wallis test, a non-parametric method to test equality of population medians amongst groups, were used instead of ANOVA.

According to the results of the tests as shown in Table 4, no significant difference within the experience group were found suggesting that practitioners of various years of experience perceive acceptable errors similarly. The organisation type group analysis reveals that clients and estimators perceive acceptable errors similarly except the subgroups of overestimate under good market for commercial buildings, overestimate under bad market for commercial buildings, and overestimate under bad market for residential buildings which clients seem to be more generous in accepting higher percentage errors.

The differences of mean absolute acceptable errors for overestimates and underestimates were further examined using t-tests (see Table 5). Apparently, the mean acceptable errors increases as the market condition changes from good to moderate and from moderate to bad. The result is somewhat expected since more uncertainty will be

present if the market condition gets worse. As a consequence, clients and estimators will incline to allow higher percentage errors in estimates. Furthermore, the mean difference between acceptable over-estimating errors and underestimating errors also reveals an increasing trend. It appears that while clients and estimators accept more errors in a worse market condition, they are more conservative towards accepting higher negative errors. This conservative attitude also explains why estimators tend to overestimate in bad years as revealed in previous empirical studies (e.g. Flanagan and Norman 1983; Gunner and Skitmore 1999).

All t-test results reject the null hypothesis that the mean absolute errors for overestimates are equal to those of underestimates. The mean absolute acceptable errors for overestimates are generally higher than those for underestimates except those for schools and industrial buildings under good market condition which show a reversed pattern. One proposition to explain this concerns the non-commercial nature of school and industrial projects. When the construction market is in boom, usually following a booming property market condition, contractors are more eager to carry out commercial projects because of a better prospect to gain profits from variations at a later stage of those projects. Thus, they are likely to put a higher risk premium to forgive the opportunity to carry out more prosperous projects. Correspondingly, clients and estimators may both recognise this in their acceptable errors for schools and industrial buildings under good market condition.

The effects of building type on mean acceptable errors were tested using the same approach for analysing experience group as described above (see Table 6). The mean differences from all ANOVA tests and median differences from all Krushal Wallis tests, used where appropriate, reject the null hypothesis that the mean acceptable absolute errors amongst the four different building types are the same. To determine which of the building types differ specifically from each other, the absolute acceptable errors for different building types were compared in pairwise using the mean difference or Mann-Whitney U rank sum tests, in case of variance heterogeneity (see Table 7). Unfortunately, performing several of the tests has a serious drawback; i.e. the more null hypotheses there are to be tested, the more likely it is that one of them will be rejected even if all of the null hypotheses are actually true. For example, if k sets of two-sample tests are produced, then the maximum possible value for this overall significance is $0.05k$. To correct the exaggerated significance levels, Fisher's least significance difference (LSD) approach is used (Kleinbaum *et al.* pp. 43-46, 443-447). The remedy for the LSD is to decrease the significance level to $0.05/k$. In this research, six (${}_4C_2$) two-sample tests are produced for each type of building (i.e., $k = 6$), and therefore the

corrected significance level for each pairwise test is 0.0083. Figure 4 shows a graphical presentation of the LSD pairwise comparisons. Except overestimates under good market conditions in which the mean acceptable error for commercial buildings is markedly higher than those of other building types, other subgroups' comparison shows similarity (being statistically indifferent) between the pair of commercial and residential buildings and the pair of schools and industrial buildings. Interestingly, the two pairs are particularly noticeable for underestimates. Again, the nature of development may help explaining this. Since one primary goal of commercial and residential developments is to make profit, clients, and to the knowledge of estimators, are likely more cautious to cost overrun and thus, less tolerable for underestimates.

Effects of underestimates and overestimates

Earlier results suggest that clients are more tolerable to overestimates than underestimates. This is probably because clients have a higher disutility or regret towards underestimates than overestimates as underestimates induce relatively more severe effects. To investigate this further, the client respondents were further asked to rate the effects of a range of percentage of underestimates and overestimates in terms of different levels of regret: 1=Well within anticipation, no particular action is necessary; 2=Borderline range of anticipation - further approval from decision makers may be required; 3=Slightly out of anticipation, some major modification of building design and cost saving exercise may be required; 4=Completely out of anticipation, a possibility of completely redesign or retender; and 5=Outrageous, there may be a revision of budget or abandonment of project. The ranges are 0% to 5%, 5% to 10%, 10% to 20%, 20% to 30%, 30% to 40%, 40% to 50%, and over 50% for overestimates, with negative equivalents for underestimates. Each respondent was asked to identify a regret level for each interval. This was repeated for each of the four building types – School, Commercial, Residential and Industrial.

The regret associated with underestimates was mapped with that of overestimates to reveal the pattern of differences between the level of regret from underestimates and that of overestimates. The procedures are summarised in the following:

1. For each estimate interval, the midpoint was recorded; e.g., if an estimate in the interval of 0% to -5% for underestimates is rated as level 1, it was recorded as -2.5%;

2. If more than one interval is rated as the same level, only the midpoint of the intervals was recorded; e.g., if the 0% to 5% and 5% to 10% intervals for overestimates are both level 1, this was recorded as 5%;
3. The threshold points of underestimates and those of overestimates for each level form sets of coordinates: $[x_1 y_1; x_2 y_2; \dots x_n y_n]$. For ease of representation, the absolute values of the threshold points for underestimates were taken. To represent the intervals selected in the examples of 1. and 2. above, the coordinates are (2.5, 5)
4. The sets of coordinates were fitted by the Ordinary Least Squares (OLS) method to produce an indifference curve. Different types of curves such as linear, quadratic, cubic and power were tested, with the root mean square error used as the selection criterion.
5. 30% of data were selected randomly and held out from the fitting procedure for *ex post* validation of the models.

The difference between the mean absolute errors of training and validation data was not significant (see Table 8) and thus, the performance of all the models was adjudged to be acceptable. The equations of overestimate (y) against underestimate (x) for each building type are:

$$\text{School } (r_{sq}=0.974): y_s = 1.7826 + 1.5327x_s - 0.0075x_s^2 \quad (1)$$

$$\text{Commercial } (r_{sq}=0.982): y_c = 1.627 + 4.9148x_c - 0.1589x_c^2 + 0.002 x_c^3 \quad (2)$$

$$\text{Residential } (r_{sq}=0.958): y_r = -3.6873 + 4.7743x_r - 0.1449x_r^2 + 0.0017 x_r^3 \quad (3)$$

$$\text{Industrial } (r_{sq}=0.962): y_i = 1.7141 + 1.7643x_i - 0.00122x_i^2 \quad (4)$$

Figures 5 to 8 shows the plots of overestimates against underestimates.

The slopes of all the indifference curves disregarding their building type are greater than 1. This reinforces the proposition that clients are more tolerable to overestimates than underestimates. Furthermore, the indifference curves show that the clients have a stronger preference for overestimates for residential and commercial buildings since the curves have greater slopes than those for school and industrial buildings. In other words, the clients have less tolerance of cost overruns for residential and commercial buildings. This may be due to the commercial nature for those developments. Each indifference curve exhibits different degrees of non-linearity. Care, however, has to be taken in interpreting this as the equivalence or otherwise of the distance between level 1 and level 2, and level 2 and level 3 etc., is not known.

CONCLUSIONS AND RECOMMENDATIONS

Previous studies concerning construction cost advice emphasize the importance of accurate estimating and minimizing estimating errors. However, as has been observed on many occasions (e.g., Fortune 2006), those who practice estimating seem to be the least concerned. They appear to feel it is their job not to make errors and are therefore of the view that they do not make them. In a situation where the majority are thus inclined, this certainly makes sense – if only to avoid the prospect of unemployment! Similarly, for those of the (Quantity) Surveying profession, errors are often perceived as something to be eliminated rather than minimised. The traditional theodolite practice of taking *eight* readings to record one measurement, for example, typifies this philosophy.

This will be of no surprise to construction industry practitioners. What is surprising perhaps, is that such idealism can survive in an industry noted for its pragmatism. The answer may be that the study of construction management is still relatively new. Until Crichton (1966), for example, for most of us there was only a dim realisation of the extent of uncertainty (and interdependence) surrounding the industry's processes. As Fortune (2006) has noted, there has been a much greater research effort aimed at developing exciting new processes than providing a serious examination of its existing ones. The result has been a retention of some of the mystical aspects of the construction business – of which cost/price estimating is one of the most notorious.

Encouragingly, the survey revealed that clients, (or more accurately the facilitators from client organisations), despite a diversity of opinions concerning the reference base for error measurement, accept the inevitability of inaccurate cost estimates and, that being so, certainly prefer conservative (over)estimates. Clearly, the opportunity losses are much greater for underestimates than overestimates.

Even more encouragingly, the Quantity Surveyors, who provide the cost advice to facilitators, generally share the facilitators' view. Of course, the management boards, financial controllers of client organisations, or development investors, to whom facilitators report, may hold a different view.

Of course, this result cannot be taken to mean overestimating *per se* is a legitimate goal in practice. Rather, it indicates that, in the presence of uncertainty, it is better to “be on the safe side” than mindlessly neutral because of the asymmetrical opportunity costs involved to the client.

How can this be developed further for the benefit of practice? The main need is for a more explicit quantification of the opportunity costs involved. Realistically, the most likely way of doing this is by the development of a disutility function as a proxy. This should then enable the development and assessment of more realistic cost models. For example, the disutility function can be applied to the selection of models in regression analysis by weighted mean squares. Unfortunately, however, the ordinal nature of the data used in the survey can only explain the asymmetry of the disutilities. In order to derive a more useful function for modelling purposes, further research needs to be conducted to determine the relative magnitude of disutility between different scales of errors.

Another possibility is that, instead of using a fixed range of potential errors in the course of cost planning and control, usually as an allowance of contingencies (Bowen and Edwards 1996), estimating errors may also be better stated explicitly. These can then be dealt with in probabilistic terms as client risk attitudes (which can be measured by their degree of aversion to underestimates) vary according to building types and market conditions. While accepting that this might not be appropriate when faced with error-intolerant clients, making errors explicit will help informed decision makers to manage the financial risks in a project.

Finally, the finding that clients, in contrast with estimators, rate the ability to identify cost sensitive elements higher than estimating accuracy suggests the need for a comprehensive value analysis in the design stage. Existing cost advice is mainly reported in the form of an estimate produced from the design information provided by the design team. It is passive and design-driven to cater for accounting needs rather than proactive and value-driven to satisfy planning needs. Although the survey does not assess the incidence of use of value analysis in practice, it is little used in Hong Kong, except an *ad hoc* basis for some significant projects or government projects applying value engineering techniques. The results of the research suggest that the formalisation of value analysis as part of the cost advice function under typical cost consulting agreements should be an appropriate form of improvement.

REFERENCES

- Akintoye, A. S., Ajewole, O., Olomolaiye, P. O. (1992) Construction cost information management in Nigeria. *Construction Management and Economics* **10**, 107-16.

- Al-Khaldi, Z. S. (1990) Factors affecting the accuracy of construction cost estimating in Saudi Arabia. MSc dissertation. UMI Dissertation Services, USA.
- Bowen, P. A., Edwards, P. J. (1985) Cost Modelling and Price Forecasting: Practice and Theory in Perspective. *Construction Management and Economics* **3**, 199-215.
- Bowen, P. A., Edwards, P. J. (1996) Interpersonal communication in cost planning during the building design phase. *Construction Management and Economics* **14**, 395-404.
- Bowen, P. A., Edwards, P. J. (1998) Building Cost Planning and Cost Information Management in South Africa. *International Journal of Procurement* (June), 16-25.
- Bowen, P. A., Wolvaardt, J. S., Taylor, R. G. (1987) Cost Modelling: a Process-Modelling Approach, in P. S. Brandon (ed) *Building Cost Modelling and Computer*, E & F N Spon, pp. 387-95.
- Brandon, P. S. (1982) *Building cost research: need for a paradigm shift?* E & FN Spon, 5-13
- Connaughton, J., Meikle, J. (1991) *The Future Role of the Chartered Quantity Surveyor*. The Royal Institution of Chartered Surveyors, Quantity Surveyors Division, London.
- Crichton, C. (ed) 1966, *Interdependence and uncertainty: a study of the building industry*, London: Tavistock Publications Ltd.
- Flanagan, R., Norman, G. (1983) The accuracy and monitoring of quantity surveyors' price forecasting for building work. *Construction Management and Economics* **1**, 157-80.
- 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**(10), 1091-8.
- Fortune, C., Hinks, J. (1998) Strategic building project price forecasting models in use - paradigm shift postponed. *Journal of Financial Management of Property and Construction* **3**(1), 3-26.
- Fortune, C. J., Cox, O. (2005) Current practices in building project contract price forecasting in the UK. *Engineering Construction and Architectural Management* **12**(5), 446 -57
- Gunner, J. C., Skitmore, R. M. (1999) Comparative analysis of pre-bid forecasting of building prices based on Singapore data. *Construction Management and Economics* **17**(5), pp. 635-46.
- Helson, H. (1964) *Adaptation-Level Theory*. New York: Harper & Row.
- Jackson, S. (2002) Project cost overruns and risk management. In A. Akintoye, (ed) *Proceedings of the 18th Annual ARCOM Conference, Glasgow Caledonian University, September, ARCOM, Reading*, pp. 99–108.

- Kahneman, N., Slovic, P., Tversky, A. (1982) *Judgement Under Uncertainty: Heuristics and Biases*. Cambridge University Press, USA.
- Kleinbaum, D. G., Kupper, L. L., Muller, K.E. (1998) *Applied regression analysis and other multivariable methods*. 3rd ed. Boston, Mass.: PWS-Kent
- Male, S. P. (1990) Professional Authority, Power and Emerging Forms of "Profession" in Quantity Surveyor. *Construction Management and Economics* **8**, 191-204.
- McCaffer, R. (1976) Contractor's bidding behaviour and tender price prediction. Department of Civil Engineering. Loughborough University of Technology.
- Morrison, N. A. D. (1984) The accuracy of quantity surveyors' cost estimating. *Construction Management and Economics* **2**, 57-75.
- Ogunlana, O., Thorpe, T. (1987) Design phase cost estimating. The state of art. *International Journal of Construction Management and Technology* **2**(4), 34-47.
- Proctor, C. J., Bowen, P. A., Le Roux, G. K., Fielding, M. J. (1993) Client and Architect Satisfaction with Building Price Advice: An Empirical Study. In CIB W55/W95 Internal Symposium on Economic Evaluation and the Built Environment, Lisbon, pp. 213-26.
- Royal Institution of Chartered Surveyors (RICS) (1992) The core skills and knowledge base of the quantity surveyor. The Royal Institution of Chartered Surveyors.
- Skitmore, R. M. (1985) *The influence of professional expertise in construction price forecasts*. Department of Civil Engineering, University of Salford.
- Skitmore, R.M. (1989) *Contract bidding in construction: strategic management and modelling*, Longman Scientific and Technical. ISBN 0 582 01855 2
- Skitmore, R. M., Cheung, F. K. T. (2006) Explorations in specifying construction price forecast loss functions. *Construction Management and Economics*, (in press).
- Skitmore, R. M., Marston, V. K. (1999) *Cost Modelling*. E & FN Spon, London.
- Skitmore, R. M., Patchell, B. R. T. (1990) Development in contract price forecasting and bidding techniques, in P. S. Brandon (ed) *Quantity Surveying Techniques: New Directions*, Blackwell Scientific, pp. 75-120.
- Skitmore, R. M., Stradling, S., Tuohy, A., Makwezalamba, H. (1990) *The Accuracy of Construction Price Forecasts: A Study of Quantity Surveyors' Performance in Early Stage Estimating*. The University of Salford.
- Wilson, A. J. (1982) Experiments in probabilistic cost modelling, in P. S. Brandon (ed) *Building cost techniques: New Directions*, E & FN Spon, pp. 169-80.

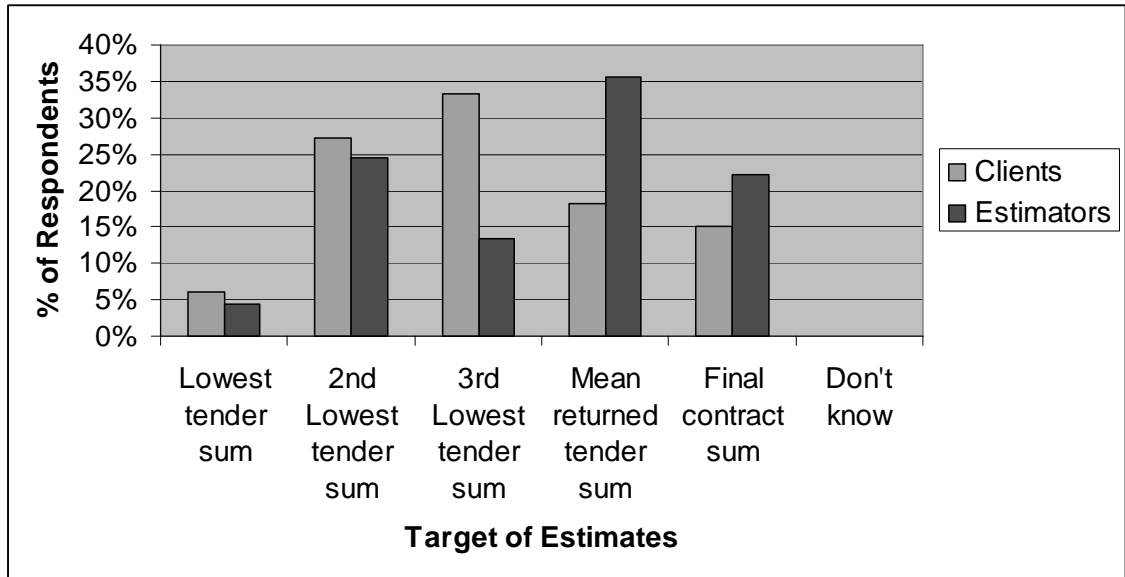


Figure 1 Preference of estimating target

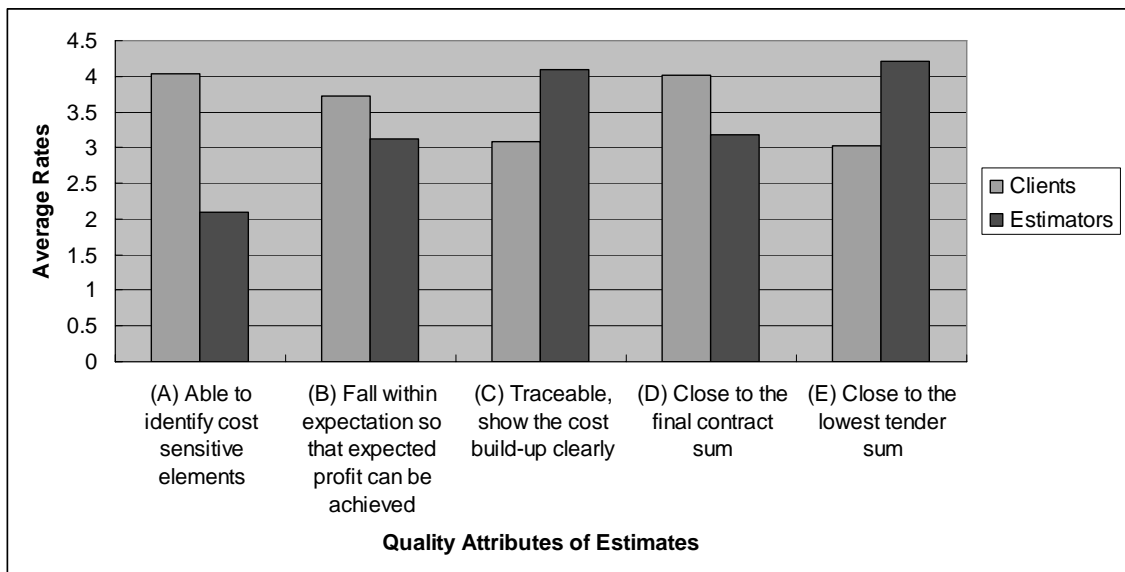


Figure 2 Average scores for quality attributes of estimates

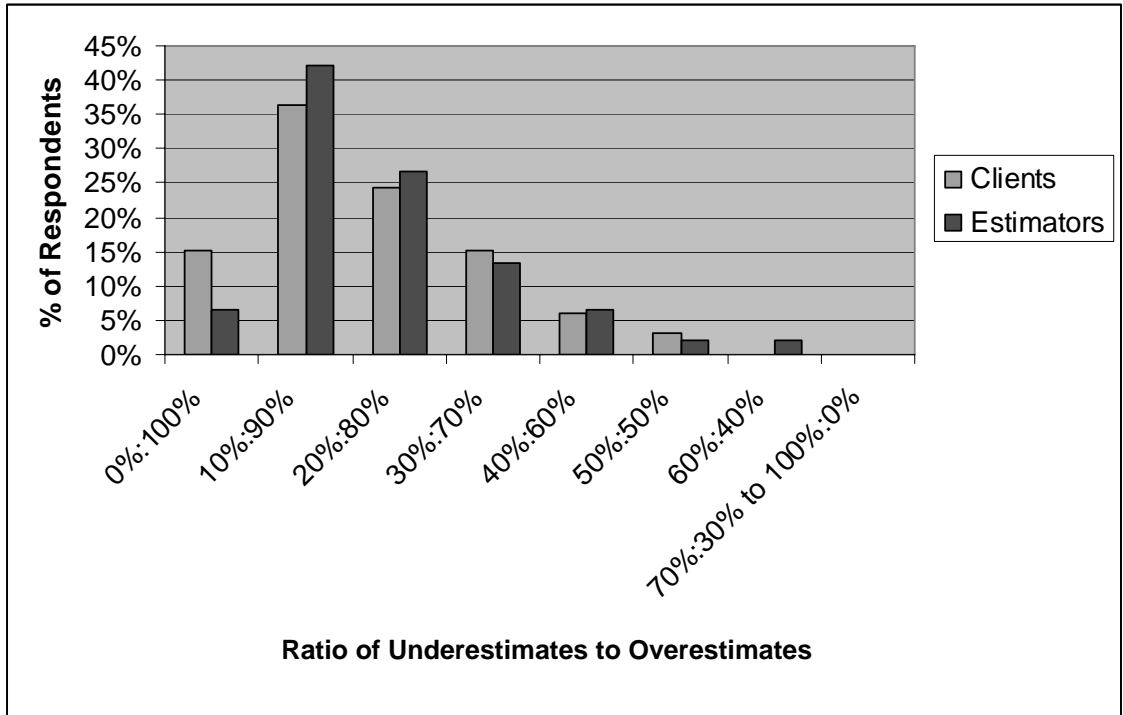
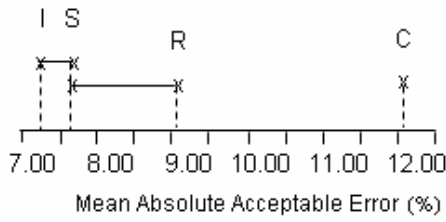
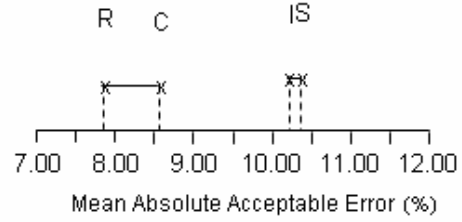


Figure 3 Occurrence ratio of underestimates to overestimates

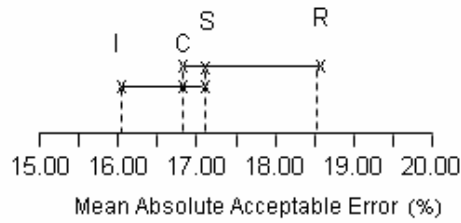
Overestimate Under Good Market



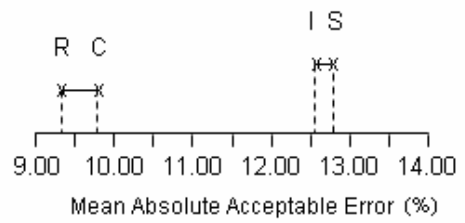
Underestimate Under Good Market



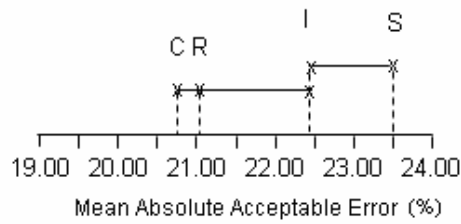
Overestimate Under Moderate Market



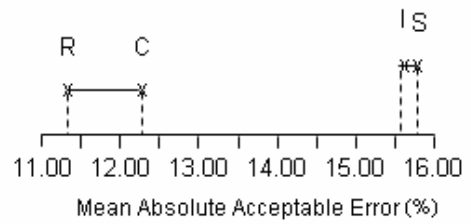
Underestimate Under Moderate Market



Overestimate Under Bad Market



Underestimate Under Bad Market



S - Schools, C - Commercial Buildings, R - Residential Buildings, I - Industrial Buildings

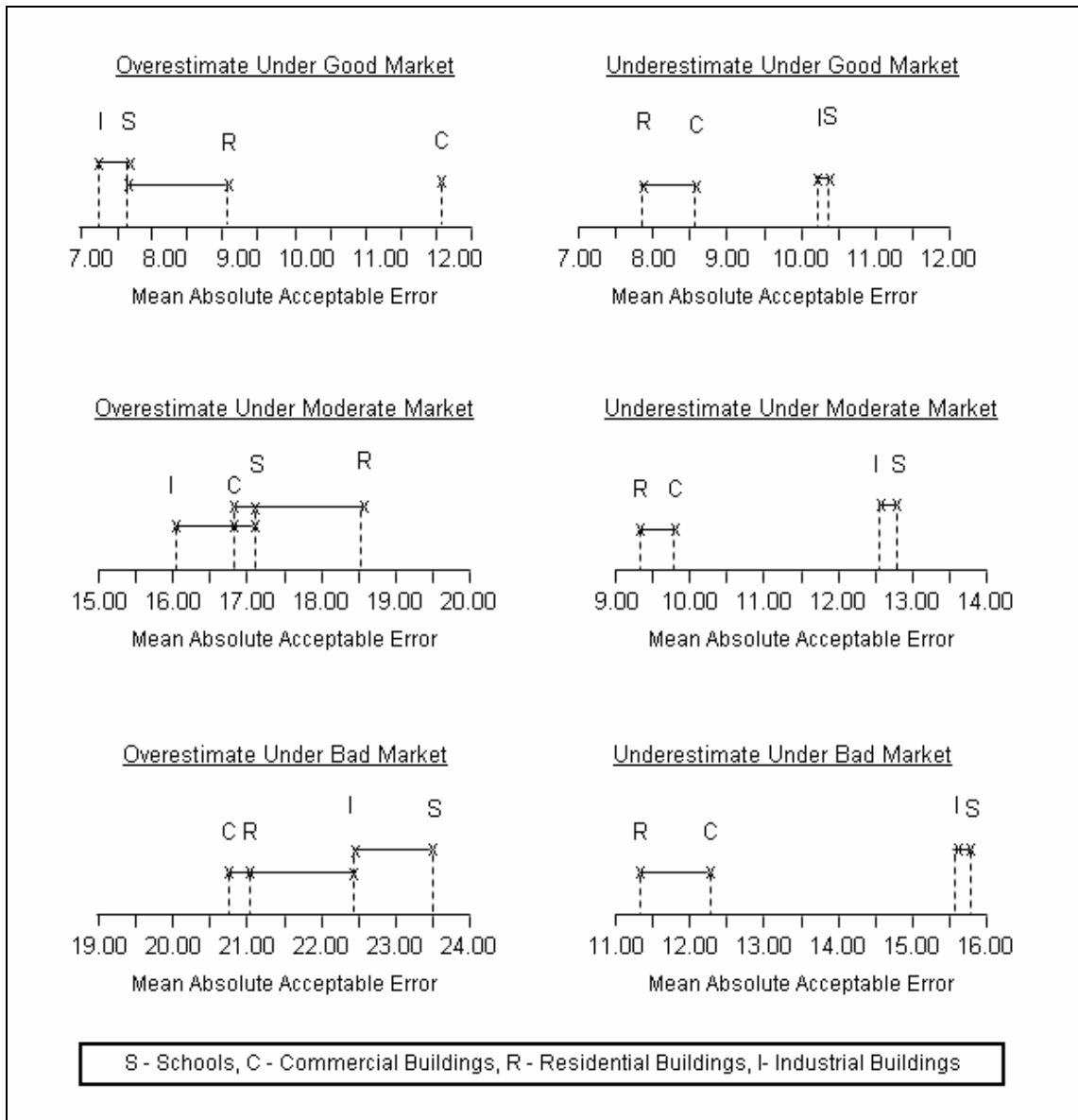


Figure 4 LSD pairwise comparisons of mean absolute acceptable percentage errors on building type (according to the results of Mann-Whitney U tests in Table 5)

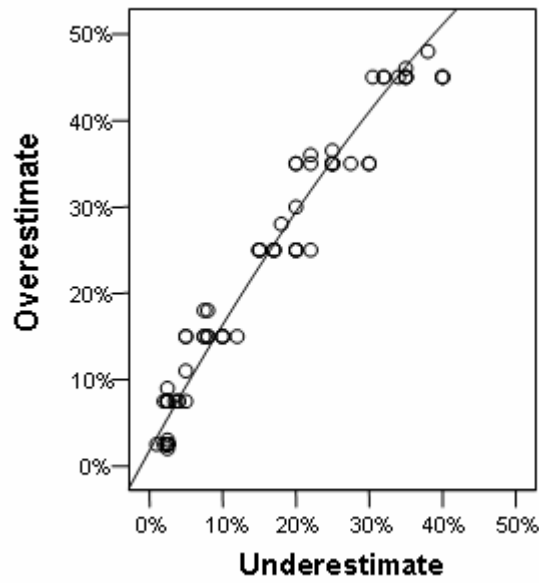


Figure 5 Overestimate vs underestimate for schools

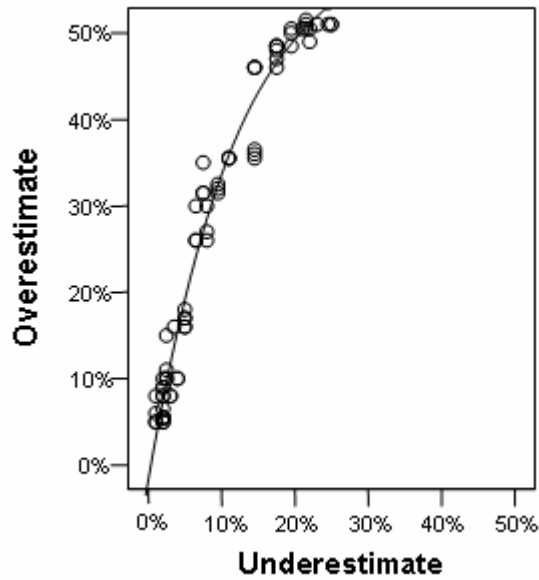


Figure 6 Overestimate vs underestimate for commercial buildings

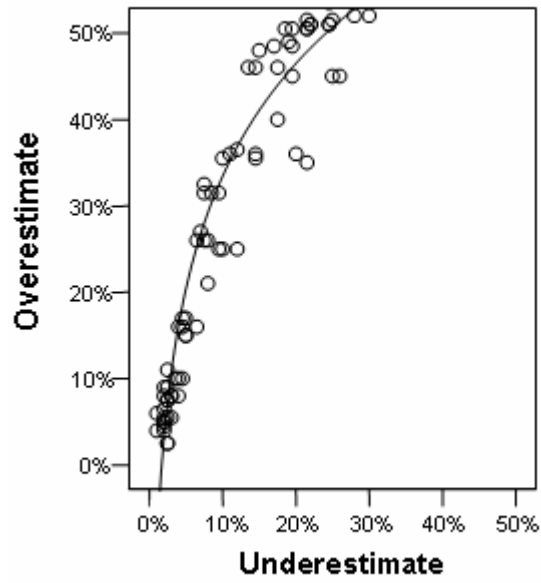


Figure 7 Overestimate vs underestimate for residential buildings

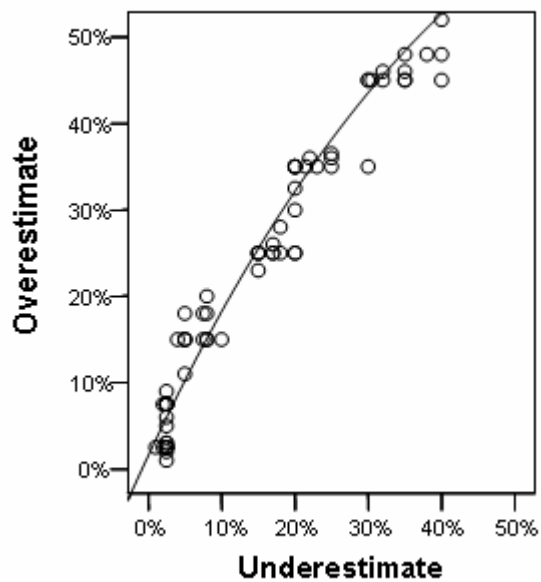


Figure 8 Overestimate vs underestimate for industrial buildings

Table 1 Cross-tabulation of ‘years of experience’ and ‘satisfaction level’

Years of Experience		< 1 year	1 - 5 years	5 - 10 years	> 10 years	<i>Total</i>
Satisfaction Level of Estimators	Very dissatisfied	0	0	0	0	0
	Dissatisfied	0	1	0	1	2
	Neutral	4	14	10	6	34
	Satisfied	1	3	3	2	9
	Very satisfied	0	0	0	0	0
	<i>Total</i>	5	18	13	9	45
Satisfaction Level of Clients	Very dissatisfied	0	0	0	0	0
	Dissatisfied	0	0	1	1	2
	Neutral	3	4	8	9	24
	Satisfied	1	2	2	2	7
	Very satisfied	0	0	0	0	0
	<i>Total</i>	4	6	11	12	33

Table 2 Cross-tabulation of the ratio of underestimates to overestimates and the level of satisfaction

Occurrence ratio of underestimates to overestimates	Very dissatisfied	Dissatisfied	Neutral	Satisfied	Very satisfied	Average Score *
	Satisfaction Level of Estimators					
0%:100%	0	0	1	2	0	0.67
10%:90%	0	0	15	4	0	0.21
20%:80%	0	0	10	2	0	0.17
30%:70%	0	0	5	1	0	0.17
40%:60%	0	0	3	0	0	0
50%:50%	0	1	0	0	0	-1
60%:40%	0	1	0	0	0	-1
70%:30% to	0	0	0	0	0	Not
100%:0%						Applicable
	Satisfaction Level of Clients					
0%:100%	0	0	1	4	0	0.8
10%:90%	0	0	9	3	0	0.25
20%:80%	0	0	7	1	0	0.13
30%:70%	0	0	5	0	0	0
40%:60%	0	0	2	0	0	0
50%:50%	0	1	0	0	0	-1
60%:40%	0	0	0	0	0	Not
						Applicable
70%:30% to	0	0	0	0	0	Not
100%:0%						Applicable

* The scores for the various satisfaction levels are: Very dissatisfied: -2; Dissatisfied: -1; Neutral: 0; Satisfied: 1; and Very Satisfied: 2.

Table 3 Mean absolute acceptable errors by organisation type and experience

	<u>Organisation Type</u>		<u>Experience</u>			
	Estimators	Clients	<1 year	1-5 years	5-10 years	>10 years
<u>School</u>						
Overestimate under Good Market	6.98%	7.55%	7.67%	6.75%	6.79%	8.05%
Underestimate under Good Market	10.51%	9.91%	9.56%	10.21%	9.83%	11.10%
Overestimate under Moderate Market	17.56%	16.30%	16.00%	17.17%	16.58%	17.81%
Underestimate under Moderate Market	12.64%	12.97%	12.78%	12.63%	12.25%	13.57%
Overestimate under Bad Market	23.84%	23.03%	22.00%	23.46%	23.04%	24.71%
Underestimate under Bad Market	15.67%	16.00%	16.11%	15.88%	15.17%	16.33%
<u>Commercial</u>						
Overestimate under Good Market	8.44%	15.94%	11.67%	10.96%	10.79%	13.29%
Underestimate under Good Market	8.73%	8.30%	8.44%	8.54%	9.33%	7.71%
Overestimate under Moderate Market	16.11%	17.76%	16.67%	16.83%	15.67%	18.14%
Underestimate under Moderate Market	10.22%	9.33%	9.44%	10.00%	10.71%	8.86%
Overestimate under Bad Market	19.18%	22.94%	20.89%	20.17%	19.33%	23.05%
Underestimate under Bad Market	12.22%	12.33%	12.56%	12.42%	13.29%	10.81%
<u>Residential</u>						
Overestimate under Good Market	9.09%	7.91%	8.67%	9.17%	8.71%	7.76%
Underestimate under Good Market	8.04%	7.61%	7.89%	7.83%	7.92%	7.81%
Overestimate under Moderate Market	19.38%	17.73%	16.22%	18.75%	19.50%	18.71%
Underestimate under Moderate Market	9.62%	9.00%	10.00%	9.92%	9.42%	8.38%
Overestimate under Bad Market	20.00%	22.42%	22.22%	20.33%	21.38%	20.90%
Underestimate under Bad Market	11.31%	11.36%	11.00%	11.58%	11.71%	10.76%
<u>Industrial</u>						
Overestimate under Good Market	6.96%	7.06%	6.56%	7.00%	6.79%	7.43%
Underestimate under Good Market	10.56%	9.79%	11.11%	10.00%	10.21%	10.14%
Overestimate under Moderate Market	16.56%	15.39%	15.00%	15.17%	16.75%	16.76%
Underestimate under Moderate Market	12.91%	12.03%	13.11%	12.38%	12.63%	12.38%
Overestimate under Bad Market	23.22%	21.33%	21.11%	22.42%	22.42%	23.00%
Underestimate under Bad Market	15.44%	15.85%	16.11%	15.00%	15.79%	15.90%

Table 4 Tests of
mean/median difference of
acceptable errors – Effects
of organisation type and
experience

Organisation TypeExperience

Type of Bias under a Market Condition	T-test assuming equal variance /							
	Homogeneity of Variances		T-test not assuming equal variance		Homogeneity of Variances		ANOVA / Kruskal Wallis Test	
	Levene		Sig.		Levene		F-Stat. /	Sig. /
	Stat.	Sig.	t	(2-tailed)	Stat.	Sig.	Chi-Sq.	Sig.
<u>Schools</u>								
Overestimate under Good Market	6.306	0.014	-1.070	0.288	2.547	0.062	1.648	0.186
Underestimate under Good Market	0.251	0.618	1.115	0.268	0.575	0.633	1.433	0.240
Overestimate under Moderate Market	0.526	0.471	1.223	0.225	0.073	0.974	0.447	0.720
Underestimate under Moderate Market	1.344	0.250	-0.494	0.623	0.285	0.836	0.829	0.482
Overestimate under Bad Market	0.410	0.524	0.552	0.582	0.054	0.983	0.448	0.720
Underestimate under Bad Market	3.614	0.061	-0.444	0.658	0.300	0.825	0.511	0.676
<u>Commercial Buildings</u>								
Overestimate under Good Market	4.181	0.044	-7.294	0.000 *	2.949	0.038	1.734	0.629
Underestimate under Good Market	0.799	0.374	0.711	0.479	0.725	0.540	1.444	0.237
Overestimate under Moderate Market	0.562	0.456	-1.541	0.128	2.400	0.075	1.039	0.380
Underestimate under Moderate Market	0.181	0.672	1.039	0.302	1.099	0.355	0.964	0.414
Overestimate under Bad Market	3.323	0.072	-3.180	0.002 *	2.231	0.092	1.941	0.130
Underestimate under Bad Market	0.297	0.588	-0.111	0.912	1.244	0.300	1.271	0.291
<u>Residential Buildings</u>								
Overestimate under Good Market	3.177	0.079	1.630	0.107	1.196	0.317	0.737	0.533
Underestimate under Good Market	0.010	0.921	0.907	0.367	0.610	0.611	0.011	0.998
Overestimate under Moderate Market	2.128	0.149	1.644	0.104	1.183	0.322	1.210	0.312
Underestimate under Moderate Market	4.241	0.043	0.833	0.407	0.958	0.417	0.956	0.418
Overestimate under Bad Market	3.594	0.062	-2.061	0.043 *	0.490	0.690	0.327	0.806
Underestimate under Bad Market	0.227	0.635	-0.063	0.950	0.808	0.493	0.316	0.813
<u>Industrial Buildings</u>								
Overestimate under Good Market	0.453	0.503	-0.250	0.803	1.514	0.218	0.661	0.579
Underestimate under Good Market	8.521	0.005	1.072	0.288	0.193	0.901	0.309	0.819
Overestimate under Moderate Market	6.278	0.014	1.318	0.192	0.106	0.957	1.044	0.378
Underestimate under Moderate Market	0.391	0.534	1.347	0.182	0.594	0.621	0.168	0.917
Overestimate under Bad Market	0.156	0.694	1.434	0.156	1.684	0.178	0.217	0.884
Underestimate under Bad Market	0.031	0.861	-0.491	0.625	0.785	0.506	0.351	0.789

^a * means statistically significant at 0.05 significance level

Table 5 Tests of mean difference of acceptable errors – Overestimates against underestimates

		<u>Mean Comparison of E_o and E_u</u>								
		<u>Mean Absolute</u>				<u>Homogeneity of</u>		<u>T-test assuming equal</u>		
		<u>Acceptable % Error</u>				<u>Variances</u>		<u>variance / T-test not</u>		
		Over-	Under-	Mean	Alternative					
Building	Market	estimate	estimate	Difference	Hypothesis	Levene		t	Sig.	
Type	Condition	(E_o)	(E_u)	(E_o-E_u)	(H_A)	Stat.	Sig.		(1-tailed)	
School	Good	7.22%	10.26%	-3.04%	$E_o < E_u$	0.611	0.436	8.114	0.000	*
	Moderate	17.03%	12.78%	4.24%	$E_o > E_u$	16.557	0.000	7.048	0.000	*
	Bad	23.50%	15.81%	7.69%	$E_o > E_u$	41.956	0.000	9.455	0.000	*
Commercial	Good	11.62%	8.55%	3.06%	$E_o > E_u$	62.489	0.000	4.360	0.000	*
	Moderate	16.81%	9.85%	6.96%	$E_o > E_u$	4.623	0.033	10.236	0.000	*
	Bad	20.77%	12.27%	8.50%	$E_o > E_u$	8.019	0.005	10.764	0.000	*
Residential	Good	8.59%	7.86%	0.73%	$E_o > E_u$	17.643	0.000	1.687	0.047	*
	Moderate	18.68%	9.36%	9.32%	$E_o > E_u$	7.785	0.006	14.897	0.000	*
	Bad	21.03%	11.33%	9.69%	$E_o > E_u$	16.744	0.000	13.449	0.000	*
Industrial	Good	7.00%	10.23%	-3.23%	$E_o < E_u$	21.095	0.000	8.176	0.000	*
	Moderate	16.06%	12.54%	3.53%	$E_o > E_u$	11.800	0.001	6.285	0.000	*
	Bad	22.42%	15.62%	6.81%	$E_o > E_u$	30.696	0.000	8.838	0.000	*

^a * means statistically significant at 0.05 significance level

Table 6 Tests of mean/median difference of acceptable errors – Effects of building type

Type of Bias under a Market Condition	<u>Building Type</u>				
	<u>Homogeneity of</u>		<u>ANOVA / Kruskal</u>		
	<u>Variances</u>		<u>Wallis Test</u>		
	Levene		F-Stat. /	Sig. /	
Stat.	Sig.	Chi-Square	Asymp. Sig.		
Overestimate under Good Market	50.017	0.000	35.071	0.000	*
Underestimate under Good Market	4.883	0.002	50.416	0.000	*
Overestimate under Moderate Market	0.432	0.730	4.857	0.003	*
Underestimate under Moderate Market	2.690	0.046	81.867	0.000	*
Overestimate under Bad Market	1.385	0.247	3.847	0.010	*
Underestimate under Bad Market	2.794	0.040	100.637	0.000	*

^a* means statistically significant at 0.05 significance level

Table 7 Pairwise comparisons of mean absolute acceptable percentage errors on building type

		<u>Mean</u>		<u>Mean</u>		<u>Mean</u>		<u>Mean</u>	
		<u>Diff. /</u>		<u>Diff. /</u>		<u>Diff. /</u>		<u>Diff. /</u>	
		<u>Mann-</u>	<u>Sig. /</u>	<u>Mann-</u>	<u>Sig. /</u>	<u>Mann-</u>	<u>Sig. /</u>	<u>Mann-</u>	<u>Sig. /</u>
Type of Bias		<u>Whitney</u>	<u>Asymp.</u>	<u>Whitney</u>	<u>Asymp.</u>	<u>Whitney</u>	<u>Asymp.</u>	<u>Whitney</u>	<u>Asymp.</u>
under a		<u>U (Z</u>	<u>Sig.</u>	<u>U (Z</u>	<u>Sig.</u>	<u>U (Z</u>	<u>Sig.</u>	<u>U (Z</u>	<u>Sig.</u>
Market	Building	<u>Stat.)</u>	<u>(2-tailed)</u>	<u>Stat.)</u>	<u>(2-tailed)</u>	<u>Stat.)</u>	<u>(2-tailed)</u>	<u>Stat.)</u>	<u>(2-tailed)</u>
Condition	Type	School		Commercial		Residential		Industrial	
Overestimate	School			-4.754	0.000 *	-2.553	0.011	-0.070	0.944
under Good	Commercial	-4.754	0.000 *			-3.118	0.002 *	-4.888	0.000 *
Market	Residential	-2.553	0.011	-3.118	0.002 *			-2.757	0.006 *
	Industrial	-0.070	0.944	-4.888	0.000 *	-2.757	0.006 *		
Underestimate	School			-4.635	0.000 *	-5.952	0.000 *	-0.056	0.955
under Good	Commercial	-4.635	0.000 *			-1.583	0.113	-3.886	0.000 *
Market	Residential	-5.952	0.000 *	-1.583	0.113			-5.142	0.000 *
	Industrial	-0.056	0.955	-3.886	0.000 *	-5.142	0.000 *		
Overestimate	School			0.218	0.758	-1.654	0.020	0.962	0.175
under	Commercial	0.218	0.758			-1.872	0.009	0.744	0.294
Moderate	Residential	-1.654	0.020	-1.872	0.009			2.615	0.000 *
Market	Industrial	0.962	0.175	0.744	0.294	2.615	0.000 *		
Underestimate	School			-6.229	0.000 *	-6.804	0.000 *	-0.771	0.441
under	Commercial	-6.229	0.000 *			-0.250	0.802	-5.904	0.000 *
Moderate	Residential	-6.804	0.000 *	-0.250	0.802			-6.606	0.000 *
Market	Industrial	-0.771	0.441	-5.904	0.000 *	-6.606	0.000 *		
Overestimate	School			2.731	0.003 *	2.474	0.007 *	1.077	0.242
under Bad	Commercial	2.731	0.003 *			-0.256	0.780	-1.654	0.073
Market	Residential	2.474	0.007 *	-0.256	0.780			-1.397	0.129
	Industrial	1.077	0.242	-1.654	0.073	-1.397	0.129		
Underestimate	School			-6.568	0.000 *	-8.271	0.000 *	-0.314	0.754
under Bad	Commercial	-6.568	0.000 *			-0.589	0.556	-5.963	0.000 *
Market	Residential	-8.271	0.000 *	-0.589	0.556			-7.363	0.000 *
	Industrial	-0.314	0.754	-5.963	0.000 *	-7.363	0.000 *		

^a * means statistically significant at 0.0083 significance level (corrected for each pairwise test)

Table 8 Mean absolute errors of training and validation data

Building type	<u>Training data</u>		<u>Validation data</u>	
	Sample size	Mean absolute errors	Sample size	Mean absolute errors
School	95	3.14	39	3.02
Commercial	105	2.10	40	2.38
Residential	123	2.56	52	2.66
Industrial	104	3.06	41	2.56