ESTIMATING PROCESSES OF SMALLER BUILDERS

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ABSTRACT

The paper describes a study of the way smaller builders price bills of quantities items for competitive tender. A series of interviews revealed some marked differences between normal practise and literature-based prescriptions. An experiment was conducted in which eight practising builders' estimators were separately presented with a representative sample of 36 bill of quantities items taken from groundwork, in-situ concrete work and masonry sections. The estimators stated the method they would normally use to price each item, their 'normal' price rate and their highest/lowest price rate. The results showed that only half the items would be priced by the prescribed 'detailed' method, the remainder being priced mainly by 'experience'. Analysis by work section, item rate, item quantity, item total, item labour content, contribution to the total of the bill, the standard deviation of the inter-estimator intra-item rates and totals, and their coefficients of variation, skewness and kurtosis indicated that the item total was the main factor determining the rating method used, although this varied in importance between work sections. An intra-estimator intra-item analysis of pricing variability generally confirmed the assumption of a constant coefficient of variation.

Keywords: Pricing, bills of quantities, item rates, variability.

INTRODUCTION

All procurement systems require, at some stage, a price to be agreed between the procurer and constructor. For most building projects, this price is tendered by a builder before carrying out the work. In this case the tender price is based on documents specifying the end product in the form of a bill of quantities, specifications and drawings, drawings only or just the procurer's brief.

Although there is a wealth of **prescriptive** literature, surprisingly little **descriptive** material is available concerning the processes employed by builders in determining a tender price. It is known however that all builders have estimating personnel, or at least someone who compiles 'estimates' which form the basis of tender prices. As a result, and the prescriptive literature is in unanimous agreement, it is generally assumed that tender prices are based on an estimate of the likely costs of construction. Over the last 20 years however, the assumption that tender prices are based on builders' genuine estimates of future expenditure has been increasingly questioned. Fine (1974), for example, has introduced the notion of the "socially acceptable price", implying that tender prices are based on the **characteristics of the finished product** rather than the **processes** involved in producing that product.

Defining the actual concepts underlying the estimating process is clearly a matter for empirical study. Empirical work in the field is however fraught with difficulty. As 'estimators' are familiar with the prescriptive literature, they tend to rationalise their work in the terms of this literature. Inevitably, they respond affirmatively to direct questions such as "do you try to estimate likely production costs?" or "do you take productivity into account?". Delving a little deeper however reveals some paradoxes. The use of feedback is a prime example. In one study of six builders' estimators (Hampson, 1979), it was found that only one estimator kept formal records of site performance. If estimators are genuinely trying to forecast actual costs, why do many not keep records of actual costs? In the absence of a resolution to this paradox, the argument exemplified by Fine must be considered to stand unrefuted.

In the research reported in this paper, the procedures used by builders in 'estimating' building work were examined. A series of interviews is described in which nine smaller builders' estimators revealed several marked differences between normal practise and literature based prescriptions. One of these differences was claimed to be in the method of 'pricing' items in bills of quantities. This is the process, formal or otherwise, of attaching a 'rate' to an item that is subsequently multiplied by the 'quantity' to give a total 'price' for that item (the procedure is termed 'rating' the item in this paper).

To investigate this further, an experiment was conducted in which eight practising builders' estimators were separately presented with a representative sample of 36 bill of quantities items taken from the groundwork, in-situ concrete work and masonry sections. The estimators stated the method they would normally use to rate each item, their 'normal' rate and their highest/lowest rate. The results showed that only half the items would be rated by the prescribed 'detailed' method, the remainder being rated mainly by 'experience'. Analysis by work section, item rate, item quantity, item total, item labour content, contribution to the total of the bill, the standard deviation of the inter-estimator intra-item (represented by the term RA) rates and totals, and RA coefficients of variation, skewness and kurtosis indicated that the item total was the main factor associated with the rating method used, although this varied in importance between work sections. Finally, the intra-estimator intra-item (represented by the term AA) variability of rates was examined in terms of the acknowledged distribution of rates by estimators. In the realisation that this work has some relevance in the formulation of measurement methods, Barnes' (1971) assumption, ie., that "the estimation of unit costs of the items is assumed to have a constant coefficient of variance" was also tested.

THE SAMPLE

To evaluate current estimating practise, a separate interview and questionnaire survey was undertaken with a sample of average practising builders' estimators. In this study, 'average' estimators were taken to be those employed in typical building companies. These were limited according to the resources at our disposal and selected on the following considerations.

Size of company

It is difficult to define the size of building firms as small, medium or large. Whilst ***Housing and Construction Statistics*** present information relating to the number of employees, this is not a completely satisfactory method of defining the size of a firm. Most builders now employ labour-only or sub-contractors to carry out the work while they undertake the management functions and provide materials and site set-up. A more accurate definition of size might be based on annual turnover, but obtaining accurate data presents a problem, as many smaller firms do not have to make such details public.

Most studies in the building industry centre on large contracting organisations. However, such organisations are not typical in the building industry. In 1987 the number of people employed by private builders totalled 961,900. 67.92% of these were employed by firms employing 114 people or less (Housing and Construction Statistics 1977-87, Table 3.10) compared with 61% in the previous decade (Housing and Construction Statistics, 1977-87, Table 3.14), and most building orders were for contracts of less than £2 million.

In view of this, a sample of smaller builders was selected, 'smaller' being defined as those companies employing 114 people or less, as representing the average building company in the industry.

Conditions of obtaining work

Current trade journals usually contain articles dealing with high value prestige projects. These large projects are regarded as prestigious not only by the client but by the architects and others. They give the appearance of being relatively well prepared and thought out with potential contractors being presented with full tender documentation and allowed a reasonable time to prepare their tenders. A considerable amount of work however, all of a minor nature, is obtained and undertaken by smaller firms. This then raises the question concerning the conditions under which these smaller firms obtain their work, i.e., are minor projects presented to builders in an identical way to major projects?

There is little press coverage of projects typified by a £50,000 alteration to the local sewage works. This type of project, when linked to a demanding client, limited design detailing, and a small budget, often proves to be most demanding. Though it does not necessarily follow that large builders do not undertake small contracts, it is certainly true that small builders undertake only small contracts and therefore their experience is restricted to and dominated by these kinds of conditions. It is to be expected therefore, that this will be reflected in the procedures of smaller builders.

Location

The Blackpool and Preston areas have a combined population of 526,458 (Key Statistics for Urban Areas, 1981), excellent transportation links, and a light industry and service industry base and a large tourist industry. This mixture of light industry, service industry and a tourist related industry combined with local and central government developments provides a local economic climate suited to smaller builders. There are few multi million pound projects and many projects are within the capabilities of these builders. As a result, this area was considered suitable to conduct research with smaller builders as it has a suitable base from which they can operate (besides being convenient for the researchers).

DATA COLLECTION AND ANALYSIS

Survey of builders

Ten smaller builders were selected at random from a comprehensive list of local builders in the Blackpool and Preston area. These builders were contacted and one estimator from each of nine of the firms agreed to take part in the study. The nine estimators were interviewed separately and informally in May and June 1990 and eight of these later completed a postal questionnaire. All the estimators worked for general building contractors who undertook all types of building work. Two firms undertook some additional speculative housing, and none undertook civil engineering work. The estimators interviewed had an average of eighteen years experience and carried out the estimating process regularly and personally. The interviews all took place in the estimators' own offices and lasted for approximately one hour, during which time freehand notes were taken by the researchers.

The questions in both the interviews and questionnaires were designed to be easily answered by practising builders' estimators. All the estimators appeared to be interested in the research and freely discussed all aspects of the estimating process with enthusiasm.

The Interviews

The interviews were used as a contact point with the estimators and to obtain their opinions on the differences between the prescriptive literature and the realities of tender preparation. The main issues discussed are summarised below.

Decision to tender. All the estimators' firms tendered for all the work sent to them at the time of the study. The amount of detail and effort that went into tender preparation was dependent on how much the firm wanted the work, a point emphasised later in the data collected by the questionnaire.

Project appreciation. Attitudes to this varied. Drawings were considered essential by all the estimators but varied in the way they were studied. Some estimators studied the drawings prior to rating, allowing for the complexity of the work in the item rates. Others studied the drawings after rating the items, adjusting for complexity by a lump sum in the Preliminaries.

None of the estimators interviewed undertook anything but the briefest of pre-tender planning, a task usually carried out by the estimators themselves. The normal procedure was to decide whether or not it was feasible to complete the work in the time specified in the tender documents. One estimator said that if it was not considered feasible, he would then make an allowance for overtime working by multiplying the liquidated damages per week by the difference between the stated contract period and a period the estimator considered reasonable and practicable.

Site visits prior to rating were not considered by all to be essential and the practise varied from visiting one in ten sites to visiting every site. Visiting the site also had different meanings to different estimators. One estimator who tried to visit every site said that if he was tendering for, say, a million pound project, he would drive past the site on his way home. He would have a look to see if there was anything of obvious interest.

This rather subjective approach of pre-tender planning and risk appraisal was justified by the estimators on two grounds: (1) the size and complexity of the projects under consideration were within their recent experience; and (2) limiting the expense involved in tender preparation was a valid way of minimising the firms' opportunity costs.

Item rates. When the estimators rated items in detail they did so in the manner prescribed in the literature ie., by careful 'build-up' of labour, material and plant costs from first principles, use of supplier and subcontractor quotations, etc. However such detailed analyses were only undertaken when an item was considered to be of significant value. Items of small financial importance were either ignored or rated at "what the job would stand".

Another aspect rarely mentioned in the literature was that of substituting alternative construction methods, particularly in temporary works, eg the use of blockwork, in lieu of plywood, in formwork to ground beams and foundations. Here the estimator would allow in his rate for blockwork instead of the more traditional plywood, if this provided a cheaper alternative, even though plywood was specified in the tender documents.

Completing the tender. Items were usually rated inclusive of profit and overheads. All the estimators considered that rating the attendance on nominated sub-contractors could only be done with experience and luck. All the estimators said that the special attendance items in bills of quantities were of little use as a guide to rating. The estimators were also in agreement on the methods used in rating the preliminaries section. All the estimators rated only what they felt the Architect would want on site, and not what was specified in the bills of quantities - another approach not prescribed in the literature.

Generally. The interviews highlighted four main areas of conflict between actual and prescribed tender pricing practices:

1) The limitation of estimating effort and tender preparation costs by using experience to rate certain items rather than detailed rate analysis. This method of rating items was undertaken to some extent by the firms of the estimators interviewed and appeared to be applied to items considered by the estimator to be of insignificant value. This confirms the view of Eastham (1990) who found some similar general variations in pricing methods between contractors.

2) The rating of items inclusive of profit and overheads - such adjudication practices that did take place being to 'fine tune' the profit allowance.

3) The limitation tender preparation costs by reducing pre-tender planning and risk appraisal to an absolute minimum.

4) The rating of preliminary items on a basis of what might eventually be wanted rather than what was actually specified.

The Questionnaire

As a consequence of result 1) above, a questionnaire survey was undertaken to gain further information on the methods of rating individual items in bills of quantities. The questionnaire contained typical bills of quantities items for Groundwork, In-situ Concrete and Masonry (Appendix A). Estimators were requested to enter a typical rate against each item. They were also asked to note if the item was rated as a result of either: detailed analysis (D); experience (E); "what the job will stand" (S); or just ignore (I).

The estimators from the original interview sample of ten small builders were asked to complete the questionnaire and nine completed questionnaires were returned. One estimator sub-divided his responses further into three stages to indicate the different approaches he used. These depended upon whether he was, a) keen, b) reasonably interested, or c) not particularly interested, in obtaining the contract. The requirements of the questionnaire had been explained previously in the informal interview with the estimators. All responses were provided anonymously. It was felt that this would yield beneficial results as most estimators were quite happy to co-operate in the survey but were less than happy to divulge extremely confidential information such as rates and labour constants. It was also felt that the source of such rates and labour constants would not be either relevant or appropriate data as the intention was only to establish the method by which estimators rated items in bills of quantities.

From a total of 324 item ratings, 173 were made by method D, 126 by method E, 14 by method S, and 11 by method I, ie., 53.4% of items were built up in detail, 38.9% were analysed from experience, 4.3% were "what the job would stand", 3.4% were ignored. If these proportions are maintained for entire bills of quantities, this would mean that just over **one half the items would be rated by the prescribed detailed method** and just under half the items would be rated without calculation. Whilst some of the experientially derived rates are likely to be based on sound judgement, these figures certainly indicate a significant departure from the prescribed approach.

Analysis of questionnaire data

It is likely that there are many factors (including behavioural factors) that determine an estimator's method of item rating. Of these, the assertion recorded in the interviews - that detailed rate analysis was only undertaken for items of significant value - was examined.

Fig 1 shows the relationship between the item total and the number of estimators rating the item by detailed analysis. Visual inspection of Fig 1 clearly indicates that the greater the item total the greater the number of estimators in the sample who used the detailed method of item rating.

To examine the extent to which these results may be generalised to the population of smaller builders, a series of statistical analyses were carried out to test the significance of the observed trends. This was done (1) by bivariate analyses of the correlation between the total number of estimators using method D of item rating and the item total, (a) for all the items and (b) by trade subsection and, (2) by a multivariate regression analysis on the trade subsections simultaneously. As is common in these kind of analyses, significance was judged at the (conservative) 5% level for all the analyses described below.

Bivariate analysis. The estimated coefficient of correlation between the frequency of the use of method D and the item total was (i) for all items $r=0.48$ ($n=37$ $p=0.001$), (ii) for Groundwork items $r=0.43$ ($n=14$ $p=0.062$), (iii) for In-situ Concrete items $r=0.34$ ($n=12$ $p=0.137$) and (iv) for Masonry items $r=0.64$ ($n=9$ $p=0.032$) confirmed the significance of a general trend to more detailed estimates with the higher valued items, except in-situ concrete items and groundwork items.

Multivariate analysis. A multiple linear regression analysis was applied. The frequency of the use of method D was the dependent variable and the item total was the independent variable with the groundworks and in-situ concrete sections being represented by dummy independent variables. This resulted in a multiple r=0.73 (F=9.345 df=4,32 p=0.000) with the constant and groundworks dummy coefficients significant at the 5% level. This again confirms the significance of a trend to more detailed estimates with the higher valued items except in-situ concrete items.

Other models. Various other models were tested, including the introduction of a squared term for the item totals and several interaction terms. None of these was found to have a significant improvement on the original model excluding the in-situ concrete variable.

Introduction of further explanatory variables. Following Runeson (1988) further potential explanatory variables were examined. These comprised for each item: the proportion of labour content; the quantity; the value contribution to the total bill; the mean inter-estimator intra-item (RA) rate; the RA standard deviation; the RA mean item total; the RA standard deviation of the item total; the RA coefficient of variation; the RA coefficient of skewness; and the RA coefficient of kurtosis.

Using Spon's price book (Spon, 1990) the proportion of labour content was estimated for each item; the value contribution of each item was taken as a proportion of the total value of all 36 items rated; and the RA coefficient of variation, skewness and kurtosis is the same for both the item rates and item total.

The values for each of these further variables, together with the number of detailed estimates recorded for the estimators, for each of the 36 items are shown in Table 1. The top right hand half of Table 2 summarises the significant correlations found between the variables. As Table 2 shows, the number of detailed estimates was correlated with the proportional labour content of the items (r=-0.36), the value contribution of the item (r=0.47), the RA mean item total (r=0.48), the RA total (r=0.42) and the RA coefficient of variation (r=-0.66). However the skewness and kurtosis were also correlated with each other and the skewness was correlated with the RA coefficient of variation.

In an attempt to find a simpler model, the logs of the item rates and item totals were taken. The significant correlations of these transformed variables are shown in the bottom left hand half of Table 2. As can be seen the RA skewness and kurtosis coefficients were now uncorrelated with the other variables, leaving all the other variables, except item quantity, correlated. As it was suspected that all these variables were in some way related to the 'size' of the item, the partial correlations were examined via the regression coefficients obtained by regressing the proportion of labour content, the quantity, the value contribution to the total bill, the mean inter-estimator intra-item (RA) log rate, the RA standard deviation, the RA mean log item total, the RA standard deviation of the item total, the RA coefficient of variation, the RA coefficient of skewness and the RA coefficient of kurtosis on the number of detailed estimates. This produced a regression model with an adjusted r^2 of 0.599 (p=0.000, SE=1.975) with only one significant variable, that of the RA mean log item total (beta=0.694). This confirmed the importance of item total in determining the rating method used[1].

From these analyses, it was therefore concluded that there was sufficient evidence to accept the proposition that a simple linear trend exists between item total and frequency of detailed estimating for all the trade sections except in-situ concrete work.

Discussion

These results confirm the fact that smaller builders' estimators use methods other than the prescribed detailed rate analysis and suggest that estimators apply such non-detailed methods for up

[1] As a matter of interest, these variables were also regressed on the transformed data standard deviations (the results are the same for both item rate and total item values). This produced an adjusted r^2 of 0.440 (p=0.001, SE=0.173) with only the **mean item rate** variable being significant (beta=-0.595)

to 50 percent of bill items, certainly for the work sections studied. Although the statistical relationships found in this present study were not always strong enough to be absolutely conclusive, there is clear evidence of a direct relationship between the method of item rating and item total for each of the three work sections examined. The expected positive correlation between the frequency of use of the prescribed detailed rating method across estimators and item total, was found for each work section although the result was not always statistically significant.

Of the nine questionnaires returned, all nine agreed that the item total was a major factor when deciding on whether or not to analyse a rate for an item in detail. Note that it is the total value of the item, i.e., unit rate multiplied by quantity, and NOT the value of the unit rate itself that is being considered here. When the estimators were requested to state what they considered a significant item total, one suggested £1,000, one £2,000, the remainder declined to answer. All nine respondents agreed that the significant amount was not a static amount but varied according to the total estimated value of the contract under consideration. Differences between estimators were found in the critical item total value, the determination of which seemed to be the result of a subjective judgement made by the estimator. Thus it appears that it is this application of judgement that causes the different methods of rating of the same item between estimators. It is likely therefore that behavioural and environmental factors such as personality, motivation, incentive and habit, all influence the use of experiential based estimating techniques particularly when dealing with items considered less than a critical value. Clearly, the factors that influence this judgement are worthy of further research.

The methods of rating bills of quantities items, identified in the survey, are clearly designed to allow the estimator to concentrate on those items that he considers to have significant influence on the final value of the estimate. The prescribed detailed method of item rating is time consuming and tender periods are short. It would appear that the combination of item rating methods is perceived to be the most efficient way for the estimator to undertake his task and arrive at a reasonably accurate tender price in the time available and with minimum opportunity cost.

The interviews clearly revealed that the estimators perceived the prescribed method of detailed item rating to be the most accurate method of estimating. The implication, therefore, is that using more subjective methods is likely to be less accurate. If this is the case, it is expected that the difference between the item ratings and the resulting actual costs associated with each item will be greater when more subjective methods are used. Whilst the data for such an analysis are not generally available, either because of confidentiality or insufficiently detailed accounting practices, this variability can be estimated indirectly by recourse to the method normally employed in PERT. Here, the estimator is required to provide a 'likely maximum' and a 'likely minimum' cost, these being essentially subjective estimates of the range of differences between estimated and actual costs. To explore this further, an additional survey was undertaken with the estimators, in an attempt to identify the range associated with the intra-estimator intra-item rates and this is described in the following section.

THE RANGE OF INTRA-ESTIMATOR INTRA-ITEM RATES

Introduction

Apparently item rates may vary considerably both within and between estimators for a variety of reasons. Little research has been undertaken to establish the range of intra-item rates applied by each estimator. Most researchers agree that no individual unit rate is 'correct', but that an estimator's rate is one of a family of such rates, any one of which could be correct (eg., Beeston, 1983; Fine, 1987). On this basis therefore the intra-estimator intra-item (AA) range or variability of rates was taken as a surrogate for degree of correctness or accuracy of the rate.

Barnes (1971:A.3.5) attempted to analyse the effect of different accuracies of item ratings on the accuracy of the total estimate by a measurable 'accuracy ratio' and concluded that "attention paid to pricing smaller value items is wasted in that it has negligible effect on the accuracy of the total." In developing his accuracy ratio theory he states that "the estimation of unit costs of the items is assumed to have a constant coefficient of variance [sic]"(1971 p A2.2). The importance of this assumption cannot be understated as the research undertaken by Barnes eventually resulted in both the civil engineering and building standard methods of measurement being revised to reduce the number of items contained in bills of quantities, supposedly without significantly affecting the accuracy of the total tender figure.

The first question of interest concerns Barnes' assumption of homogeneity of AA variability. This can be approached either by applying one of the usual homogeneity tests, such as Bartlett's test, or by testing for the existence of trends, such as a correlation between item variability and item total or rating. In the work described next, the AA variability is analysed in terms of both standard deviations and coefficients of variation.

Data

The ten estimators were sent a further questionnaire comprising the same items as in the previous study (Appendix A - see italics). They were requested to insert against each item:-

a) lowest rating they would consider using (ie., proxy for minimum expected cost)

b) 'normal' rating (ie., proxy for mean expected cost)

c) highest rating they would consider using (ie., proxy for maximum expected cost)

These questionnaires were administered in March 1991. Seven estimators completed them fully and a further estimator completed the groundwork section only. All the questionnaires were completed anonymously. No further discussions were possible with the estimators on specific information arising from the questionnaire.

Analysis 1

It was clear from visual inspection of the unit rates that in virtually every case the normal rate is closer to the minimum rate than the maximum rate, ie., there is a positively skewed distribution - a normal occurrence for these kind of data. Therefore the standard deviation (see Appendix B) was estimated by the PERT approximation for Beta distributions (Loomba, 1978):

$$\sigma = \frac{b - a}{6}$$

where σ = estimated standard deviation

b = maximum value

a = minimum value

The data included an item for steel reinforcing that was rated by all estimators at a comparatively high rate of many hundreds of pounds, whilst most items varied in value between a few pence and 70 or 80 pounds. To remove the possibility of any undue distortion, the analyses were conducted both with and without this outlier.

The item ratings and their estimated AA standard deviations were plotted for each estimator both with and without the outlier. Visual inspection suggested that the AA standard deviation generally increases as the item rate increases. The regression line of item ratings on the AA standard deviation was also plotted. The slopes, together with the correlation coefficients both with and without the outlier, are summarised in Table 3.

As can be seen from Table 3, the presence of the outlier did cause some apparent distortion of the results for estimators 2 and 6. However in the remaining cases there was a statistically significant correlation between the item ratings and their AA standard deviations. In both cases where the results were not significant, the estimators had attributed a large number of items with an AA standard deviation between 0 and 1. The remaining items had a limited spread of AA standard deviation, yet estimator 2 had one item with an AA standard deviation of 171, the highest recorded AA standard deviation of any rate by any estimator. It would appear that both estimators 2 and 6 limit their range to a very large extent, with estimator 6 having 21 out of 36 ratings with a zero AA standard deviation.

A reliability analysis was carried out to check on whether the observed differences in AA standard deviations between estimators were 'real' rather than just simply artifacts of the sampling process. This was done for the seven estimators for which a full set of data was available. This analysis produced a Cronbach alpha value of 0.6618 (standardised Cronbach alpha = 0.9453) with an average inter-estimator correlation of 0.8381. The lack of any probability levels associated with the Cronbach alpha statistic makes interpretation of this result rather subjective, but this was taken to indicate a reasonable level of reliability. As a further check, a components of variance analysis was made (Table 4). This indicated conclusively that there were no significant differences between the estimators. Thus it was decided to continue the analysis with the data pooled across the estimators, ie., all the estimators were treated as if they behaved in the same way.

Having pooled the data, the first test was to check the differences between AA standard deviations. A oneway ANOVA showed the differences to be statistically significant ($F_{35,231}$=3.1177, p=0.0000; $F_{34,225}$=2.4535, p=0.0001 with outlier removed). The next test examined the significance of the association between the AA standard deviations and their AA mean and total. A two-way analysis of covariance (ANCOVA), where all 'effects' were adjusted concurrently, indicated the existence of significant item effects (F=1.88, p=0.003; F=4.326, p=0.000 with outlier removed) and AA means effects (F=241.4, p=0.000; F=240.8, p=0.000 with outlier removed). It did not indicate the existance of significant of item totals (F=0.027, p=0.602) except with the outlier removed (F=0.001, p=0.974). A further two-way ANCOVA indicated the existence of work section effects (F=4.336, p=0.014) and AA means effects (F=221.818, p=0.000) but not with item totals (F=26.843, p=0.642). Of course the nature of the data collected was such that it was not possible to test if the work section effect subsumed any item effects.

The results of regressing AA means and item totals on the AA standard deviations are summarised in Table 5. This table confirms the significance of the slopes of the regression lines for each work section and the correlation of AA standard deviations with AA means and not item totals.

Discussion

The AA standard deviation is a measure of the dispersion of values around the AA mean, and can be taken to represent the family of rates for each item. The correlation between AA standard deviation and item ratings is not surprising as it is usual for researchers in this field to assume the existence of a proportional relationship, and hence the general use of coefficients of variation. What is a little surprising however, is the lack of any significant correlation between AA standard deviation and item total, ie., the AA standard deviation is unaffected by the quantity of work represented by the item.

Having established the existence of a 'size' effect in using AA standard deviation as a measure of variability, attention was next turned to examining more closely the nature of this relationship and, in particular, the possible neutralising effects of using AA coefficients of variation as a substitute measure of variability.

Analysis 2

The same procedure as Analysis 1 was followed using the AA coefficient of variation *in lieu* of the AA standard deviation. Table 6 summarises the results. Statistically significant correlations were obtained in only two cases out of fifteen.

The Cronbach alpha value was 0.3870 (standardised Cronbach alpha = 0.3201) with an average inter-estimator correlation of 0.0743, suggesting quite poor consistency between the estimators. The components of variance analysis (Table 7), indicated that there were no significant differences between the estimators. Again it was decided to continue the analysis with the data pooled across the estimators ie. all the estimators were treated as if they behaved in the same way.

Having pooled the data, the first test was to check the differences between AA coefficients of variation. A oneway ANOVA indicated the differences to be statistically significant ($F_{35,231}$=1.478, p=0.0489; $F_{34,225}$=1.503, p=0.0443 with outlier removed). The next test was to find if the differences between AA coefficients of variation were significantly associated with differences between their AA mean and total values. A two-way analysis of covariance (ANCOVA) indicated the existence of significant item 'effects' (F=1.57, p=0.028; F=1.634, p=0.020 with outlier removed) and AA means effects (F=1.570, p=0.028; F=1.634, p=0.020 with outlier removed) but not with item totals (F=0.005, p=0.941; F=0.008, p=0.929 with outlier removed). A further two-way ANCOVA indicated the existence of work section effects (F=7.138, p=0.001; F=4.796, p=0.009 with outlier removed) but no AA means effects (F=1.146, p=0.285; F=0.008, p=0.927 with outlier removed) or with item totals (F=0.431, p=0.512; F=0.377, p=0.540 with outlier removed). Again, the nature of the data collected was such that it was not possible to test if the work section effect subsumed any item effects.

What is clear from this analysis is that there are no linear item size effects once the work section effects are removed. The possibility remains however that the relationship between the item size and AA coefficients of variation differs between sections (the ANCOVA analysis not including interaction terms due to the limited amount of data available).

The results of regressing AA means and item totals on the AA coefficients of variation by work sections are summarised in Table 8. This table indicates the significance of the slopes of the regression lines for each individual work section and the significant correlation of AA coefficients of variation with AA means and not item totals.

Overall, these results indicate that there is no significant linear relationship between AA coefficients of variation and item totals for each or all of the work sections. There is a significant positive linear relationship between the AA coefficients of variation and the AA means for the ground works and concrete works sections.

Barnes' Assumption

In view of its importance, the assumption by Barnes that all items have a constant AA coefficient of variation was examined in more detail.

The AA coefficients of variation for all rates submitted by the estimators are categorised in Table 9. This suggests that, although the assumption proposed by Barnes is not statistically valid according to the above, it may not be an unreasonable proposition particularly when the following is considered. Out of 267 items, a total of 21 have an AA coefficient of variation greater than 10. Of these, 6 of the items related to earthwork support or disposal of water, which can reasonably be considered high risk items with extremes of rates available - a high AA coefficient of variation in such items is therefore not unreasonable. Most of the remaining items with an AA coefficient of variation in excess of 10% had very high maximum rates applied to them which tended to distort the AA coefficient of variation.

Those items in the band over 5% and not exceeding 10% AA coefficient of variation totalled 50. Of these, 31 exceeded 5% but did not exceed 6% AA coefficient of variation with a further 6 in the 6% to 7% AA coefficient of variation range. Of these items it is the maximum rate that distorts the figures and increases the AA coefficient of variation. Considering how infrequently an estimator gets the opportunity to apply the maximum rate and how much more frequently rates applied will be somewhere between the minimum and normal, Barnes' assumption appears to be more reasonable.

Barnes' hypothesis, that "attention paid to pricing smaller value items is wasted in that it has negligible effect on the accuracy of the total", was now tested. Barnes based his findings on data from rated bills of quantities, these showing final tender figures and a figure for each individual rate. Should several bills of quantities be available for the same project a comparison could be made between the figures inserted in the bills by each estimator for each item. However each estimator would insert only one rate against each item, thus Barnes could not have known the AA variability.

The data produced by this research are an indication of the AA variability for each of 36 bill items.

The coefficient of variation of the total of the 36 items is

$$Vt = \frac{\sqrt{\Sigma q_i^2 S_i^2}}{\Sigma q_i x_i}$$

V_t = Variability of total

q_i = quantity of item

S_i = AA standard deviation of item

x_i = AA mean of item

As q_i is known and both S_i and x_i are estimated from the data it is possible to calculate V_t. If the hypothesis proposed by Barnes is correct then the greatest effect on the variability of the total figure is caused by the high value items/rates with lower value items/rates having progressively less effect as they reduce in value. The 36 items were therefore rank ordered by item total value and V_t calculated for sets of 1, 2, ... , 36 items. This was repeated for all the estimators and the results are shown in Fig 2. This shows that, in virtually every case, V_t reduces very rapidly to a near minimum with only a few of the highest rated items. This appears to be the case no matter what starting level of variability is considered. Thus, if the intra-item variability measure is equated with Barnes' intra-item accuracy, these results would appear to confirm the notion that many small value items have a negligible effect on the accuracy of the final figure. This fact lends some support to the hypothesis that detailed attention paid to rating many small value items is likely to be wasted because of the excessive opportunity costs involved.

Conclusion

1. The relationship between the value of the unit rate and the extent of the family of rates as measured by the AA standard deviation was found in the majority (13 out of 15) of cases to be significant. As one would expect, high value items tend to have a higher AA standard deviation than low value items. This indicates that the range of rates available for such items is more extensive than for low value items. This would support the viewpoint that estimators make the most beneficial use of their time without reducing estimate accuracy by concentrating their efforts on high value items.

2. The assumption by Barnes, that all items have a constant AA coefficient of variation is reasonable. The vast majority of items has an AA coefficient of variation of less than 7%, with 73% of items examined having an AA coefficient of variation of less than 5%.

3. The hypothesis by Barnes that little attention is paid to rating small value items is supported by the results for each of the eight builders' estimators examined. In each case the total cost variability reduced rapidly with the items of significant cost and did not appear to reduce further when the items of minor cost were considered.

SUMMARY AND CONCLUSIONS

This paper describes a study of the estimating processes of smaller builders. The study comprised firstly, a series of interviews revealing four major differences between the standard texts and practice: (1) limiting of estimating effort and cost in tender preparation by using experience to rate certain items rather than detailed rate analysis; (2) rating items inclusive of profit and overheads; (3) limiting the cost of tender preparation by reducing pre-tender planning and risk appraisal to an absolute minimum; and (4) rating of preliminary items on a basis of what might eventually be wanted rather than what was specified in the tender documents. This was followed in the second part of the study by a questionnaire survey concerning the estimators' approach to rating bills of quantities items. An experiment involving eight builders' estimators separately rating an extract from a bill of quantities containing 36 items, is described from which it was found that only just over half of the items were rated by the detailed methods prescribed in the standard texts. The remaining items were rated mainly by 'experience'. In attempting to identify which items are more likely to be rated by detailed methods, several potential variables were analysed including the work section containing the item, the item rate, the item quantity, the item total, the labour content of the item, the contribution of the item total to the total of the bill, the RA standard deviation of rates, the RA standard deviation of item totals, the RA coefficients of variation, skewness and kurtosis. The result shows that the item total (rate multiplied by quantity) is the one significant determining variable, although the degree of influence of this differs between work sections.

In the final part of the study the **intra** estimator variability of item rating was examined by questionnaire survey through the estimators' admitted range of rating values. On the assumption that this reflected the range of accuracy with which the items are rated (costed), Barnes' assumption of constant AA coefficient of variation was tested and found to be reasonable.

It is considered that this work is important in contributing to the 'bottom-up' understanding of the mechanisms underlying movements of building prices at both project, market and industry levels. At the project level, the economic consequences of design decisions are embodied in builders' pricing behaviour. As the nature of most procurement practises is to delay the builders' involvement until after the major design decisions are made, it is necessary to understand, and therefore predict, such behaviour in advance. Similarly, the aggregated builders' pricing behaviour has an impact at both market and industry levels. By modelling this behaviour, it may be possible to forecast in advance the economic consequences of design decisions for individual projects and ultimately changes in design policies for markets and the industry (eg changes in building regulations and/or design codes). A further and more immediate application is in the formulation of measurement codes. By considering the pricing practises of smaller builders, it should be possible to gauge the benefit/cost effects of new approaches.

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Appendix A: Sample items

Local Authority School; floor area 500m^2; location within 5 miles of head office.

Bill of Quantities prepared in accordance with SMM7.

Please look at the following extracts from the Bill of Quantities for the above. If you were tendering for the contract, which items would you price in detail (please mark these D), which would you price from experience (please mark E), which items would you ignore (please mark I), and which you would price for what the job will stand (S).

Please insert in the appropriate column:

a) lowest unit rate you would generally consider using

b) normal rate ie., one generally used

c) highest rate you would generally consider using

Item.			Total responses D	E	I	S
	GROUNDWORK					
	Excavating and filling					
1.	Excavating topsoil for preservation average depth 150mm	400 m^2	3	5	1	0
2.	Excavating to reduce levels; maximum depth not exceeding 0.25m	10 m^3	3	5	1	0
3.	Ditto not exceeding 1.00m	300 m^3	5	3	1	0
4.	Excavating basements and the like; maximum depth not exceeding 2.00m	50 m^3	5	3	1	0
5.	Excavating pits (12 Nr) ditto	10 m^3	3	5	1	0
6.	Excavating trenches; width over 300; maximum depth not exceeding 1.00m	225 m^3	3	5	1	0
7.	Working space allowance to excavations; reduce levels; basements or the like	30 m^2	5	2	2	0
8.	Earthwork support; maximum depth not exceeding 1.00m; distance between opposing faces not exceeding 2.00m	200 m^2	0	4	4	1
9.	Disposal; surface water	Item	0	2	1	6
10.	Disposal excavated material off site	555 m^3	6	3	0	0
11.	Ditto on site	100 m^3	5	4	0	0
12.	Filling to excavations, average thickness not exceeding 0.25m arising from excavations	60 m^3	3	6	0	0
13.	Ditto obtained off site; clean broken stone	60 m^3	5	4	0	0
14.	Surface treatment; compacting; filling;					

	blinding with sand	400 m^2	3	4	0	2
15.	Surface treatment; compacting; bottoms of excavations	400 m^2	2	5	1	1
	IN-SITU CONCRETE/LARGE PRECAST CONCRETE					
	Plain in-situ concrete; BS 5328; designed mix C25; 20 aggregate					
16.	Foundations	100 m^3	7	2	0	0
17.	Ground beams	5 m^3	7	2	0	0
18.	Filling to hollow walls	5 m^3	6	3	0	0
	Reinforced in-situ concrete; BS5328; designed mix C35; 20 aggregate; vibrated					
19.	Beds; thickness not exceeding 150mm	10 m^3	8	1	0	0
20.	Beds; thickness 150-450mm	80 m^3	8	1	0	0
21.	Beds; thickness over 450mm	20 m^3	8	1	0	0
22.	Columns	10 m^3	7	2	0	0
23.	Staircases	5 m^3	7	2	0	0
	Formwork for in-situ concrete					
24.	Sides of foundations; plain vertical height 250-500mm	200 m	7	2	0	0
25.	Soffits of slabs; slab thickness not exceeding 200mm; horizontal	15 m^2	6	3	0	0
	Reinforcement for in-situ concrete					
26.	Bar; 12mm diameter; straight	0.5 t	5	4	0	0
	Worked finishes					
27.	Power floating	400 m^2	3	6	0	0
	MASONRY					
	Concrete commons in cement mortar (1:3)					
28.	Walls; half brick thick; vertical	20 m^2	7	2	0	0
	Nori red rustic facings in cement mortar (1:3)					
29.	Walls; half brick thick; fair face and struck jointed one side; vertical	600 m^2	9	0	0	0
30.	Walls; one brick thick; one face in facings fair face and struck jointed; one face in concrete commons fair face and struck jointed; vertical	50 m^2	9	0	0	0
	Celcon concrete blockwork in cement mortar (1:3)					

31.	Walls; 100 thick; vertical	590 m^2	8	1	0	0
32.	Closing cavities 50 wide with 100 blockwork; vertical	50 m	3	6	0	0
	Accessories/sundry items					
33.	Forming cavities; in hollow walls; 50 wide; butterfly wall ties 5Nr/m^2	595 m^2	1	7	0	1
34.	Damp proof courses; hyload; width not exceeding 225mm; vertical	25 m	2	7	0	0
35.	Ditto horizontal	195 m	2	7	0	0
36.	Ditto raking	10 m	2	7	0	0
		Total	173	126	14	11

Appendix B: Item rates

Item	Estimator 1	2	3	4	5	6	7	8
1	0.18	1.18	0.28	0.20	0.62	0.19	0.30	0.53
	0.012	***0.408***	***0.005***	***0.007***	***0.013***	***0.023***	***0.008***	***0.028***
2	1.20	2.20	1.58	1.66	3.39	0.74	2.00	6.50
	0.083	***0.167***	***0.038***	***0.168***	***0.077***	***0.012***	***0.067***	***0.353***
3	0.95	2.20	1.58	1.46	2.54	0.74	2.00	2.75
	0.083	***0.167***	***0.038***	***0.167***	***0.058***	***0.012***	***0.067***	***0.150***
4	3.50	6.50	5.70	6.10	2.54	8.99	6.67	7.50
	0.167	***0.333***	***0.142***	***0.342***	***0.058***	***0.143***	***0.183***	***0.407***
5	5.25	11.00	7.12	7.70	10.15	4.10	11.05	7.50
	0.208	***0.375***	***0.170***	***0.348***	***0.232***	***0.065***	***2.197***	***0.402***
6	4.95	12.00	4.75	5.14	5.07	4.95	7.78	4.50
	0.217	***0.333***	***0.113***	***0.100***	***0.117***	***0.078***	***0.183***	***0.250***
7	3.75	12.00	22.75	2.46	6.40	9.44	13.82	12.50
	0.150	***0.333***	***0.400***	***0.123***	***0.137***	***0.150***	***0.175***	***0.678***
8	0.50	3.50	0.60	1.10	1.26	5.89	3.03	3.70
	0.117	***0.600***	***0.015***	***0.058***	***0.038***	***0.093***	***3.047***	***0.202***
9	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00
	0.000	***16.667***	***41.667***	***0.000***	***0.000***	***12.500***	***0.000***	***0.000***
10	6.50	7.00	6.00	5.58	7.70	9.14	6.15	8.20
	0.442	***0.333***	***0.333***	***0.320***	***0.117***	***0.145***	***0.900***	***0.443***
11	2.20	2.10	3.00	1.16	2.20	1.42	2.94	4.20
	0.167	***0.508***	***0.333***	***0.042***	***0.033***	***0.023***	***0.032***	***0.227***
12	3.00	3.89	1.42	2.76	3.39	6.66	5.80	15.00
	0.167	***0.185***	***0.083***	***0.057***	***0.077***	***0.105***	***0.000***	***0.812***
13	13.50	12.00	14.50	16.16	16.57	19.53	14.48	15.00
	0.692	***0.242***	***0.367***	***0.577***	***0.367***	***0.310***	***1.368***	***0.812***
14	0.45	0.80	0.60	1.92	0.76	1.29	1.12	1.20
	0.033	***0.077***	***0.043***	***0.077***	***0.023***	***0.020***	***0.000***	***0.065***
15	0.25	0.50	0.05	0.34	0.27	0.37	0.67	0.60
	0.033	***0.117***	***0.000***	***0.010***	***0.010***	***0.007***	***0.103***	***0.032***
16	51.00	60.00	58.58	59.96	57.88	68.62	53.94	
	1.000	***3.200***	***1.903***	***1.475***	***1.475***	***1.423***	***0.000***	
17	52.50	65.00	65.00	62.69	64.96	126.00	59.36	
	0.833	***2.500***	***1.667***	***1.363***	***1.738***	***2.000***	***0.000***	
18	55.00	55.00	75.00	63.38	116.88	76.65	66.32	
	1.083	***2.833***	***1.167***	***1.088***	***3.625***	***1.217***	***0.000***	
19	57.50	68.00	65.00	69.72	68.51	75.06	65.76	
	0.917	***0.500***	***1.167***	***1.283***	***1.868***	***1.192***	***0.000***	
20	55.00	64.00	64.00	67.60	61.43	75.06	60.24	
	1.000	***0.667***	***1.667***	***1.432***	***1.607***	***1.192***	***0.000***	
21	52.50	58.00	62.00	67.60	54.34	73.15	56.56	
	0.917	***0.000***	***1.333***	***1.432***	***1.343***	***1.147***	***0.000***	
22	57.50	125.00	75.00	72.60	86.23	77.66	109.02	
	0.833	***0.000***	***1.250***	***5.492***	***2.525***	***1.233***	***0.000***	
23	70.00	132.00	75.00	72.60	100.40	67.34	74.96	
	1.333	***0.000***	***1.250***	***5.492***	***3.050***	***1.068***	***0.000***	
24	5.50	5.50	5.00	5.38	14.53	20.21	14.76	
	0.417	***0.292***	***0.417***	***0.663***	***0.495***	***0.322***	***0.000***	
25	18.75	7.00	45.00	22.38	7.55	29.65	17.36	
	0.750	***0.210***	***1.167***	***1.450***	***0.255***	***0.470***	***0.000***	
26	495.00	1000.00	360.00	601.00	663.80	722.09	872.50	
	12.500	***171.667***	***16.667***	***37.333***	***17.900***	***11.462***	***7.352***	
27	1.60	1.00	3.00	1.32	1.35	2.78	1.50	
	0.058	***0.000***	***0.167***	***0.032***	***0.050***	***0.045***	***0.187***	
28	10.50	25.00	18.20	20.38	17.26	19.29	20.05	
	0.250	***1.333***	***0.450***	***0.977***	***0.530***	***0.307***	***0.000***	
29	30.75	35.00	53.07	36.72	44.48	31.53	39.52	
	0.500	***1.067***	***1.150***	***1.090***	***1.190***	***0.500***	***0.000***	
30	41.25	60.00	84.53	62.74	61.33	51.77	60.03	
	0.750	***3.400***	***2.167***	***1.313***	***1.705***	***0.822***	***0.000***	
31	10.75	24.00	18.00	17.79	20.95	10.44	19.80	

	0.250	*0.667*	*1.000*	*0.387*	*0.600*	*0.165*	*0.098*
32	1.00	4.00	1.20	4.96	1.08	2.04	4.39
	0.117	*0.400*	*0.067*	*0.147*	*0.040*	*0.032*	*0.000*
33	0.75	3.00	0.50	1.39	1.00	1.15	0.69
	0.067	*0.167*	*0.008*	*0.075*	*0.030*	*0.018*	*0.000*
34	1.50	2.50	0.76	1.49	1.92	2.76	1.66
	0.050	*0.333*	*0.013*	*0.028*	*0.050*	*0.043*	*0.000*
35	1.50	1.50	0.72	1.49	2.19	1.42	1.53
	0.050	*0.167*	*0.010*	*0.028*	*0.060*	*0.023*	*0.000*
36	1.60	3.50	0.76	1.49	1.26	2.10	1.53
	0.050	*0.342*	*0.017*	*0.028*	*0.038*	*0.033*	*0.000*

Standard deviations given in *italics*.

Item	Lab (%)	Q	cntrib (%)	mean rate	SD	mean total	SD	COV	skew[1]	kurtosis
1	22	400	0.46	0.43	0.3424	174.00	136.9713	78.72	**1.76**	3.11
2	22	10	0.10	2.41	1.8285	24.09	18.2855	75.91	**1.93**	4.05
3	22	300	1.57	1.78	0.7227	533.25	216.8125	40.66	-0.14	-1.25
4	20	50	0.80	5.94	2.0764	296.88	103.8188	34.97	-0.44	-0.07
5	20	10	0.19	7.98	2.5859	79.84	25.8595	32.39	-0.15	-1.24
6	20	225	3.06	6.14	2.5809	1382.06	580.7065	42.02	**2.13**	4.39
7	20	30	0.81	10.39	6.4959	311.70	194.8766	62.52	0.75	0.81
8	72	200	1.43	2.45	1.9011	489.50	380.2146	77.67	0.73	-0.29
9	-	-	0.04	25.00	46.2910	25.00	46.2910	185.16	**1.44**	0.00
10	-	555	10.27	7.03	1.2241	3903.73	679.3898	17.40	0.64	-0.62
11	53	100	0.76	2.40	0.9680	240.25	96.8028	40.29	0.69	0.56
12	47	60	1.32	5.24	4.2861	314.40	257.1644	81.80	**2.04**	4.62
13	18	60	2.25	15.22	2.2591	913.05	135.5434	14.85	0.73	1.24
14	28	400	1.07	1.02	0.4694	407.00	187.7719	46.14	0.88	0.83
15	100	400	0.46	0.38	0.2023	152.50	80.9215	53.06	-0.09	-0.41
16	17	100	9.06	58.57	5.5407	5856.86	554.0720	9.46	0.67	1.51
17	21	5	0.55	70.79	24.7654	353.94	123.8272	34.99	**2.45**	6.30
18	36	5	0.55	72.60	21.3184	363.02	106.5920	29.36	**1.80**	3.74
19	37	10	1.04	67.08	5.3446	670.79	53.4457	7.97	-0.55	1.78
20	32	80	7.91	63.90	6.2844	5112.34	502.7519	9.83	0.63	1.24
21	29	20	1.88	60.59	7.4871	1211.86	149.7423	12.36	0.82	-0.44
22	43	10	1.31	86.14	23.2135	861.44	232.1348	26.95	0.80	-0.13
23	49	5	0.65	84.61	23.5816	423.07	117.9081	27.87	**1.75**	2.56
24	74	200	3.10	10.13	6.2471	2025.14	1249.4169	61.70	0.74	-1.33
25	68	15	0.49	21.10	13.2154	316.48	198.2303	62.64	0.90	0.80
26	27	0	0.52	673.48	217.5849	336.74	108.7924	32.31	0.13	-0.48
27	71	400	1.11	1.79	0.7749	717.14	309.9653	43.22	**1.00**	-0.79
28	59	20	0.57	18.67	4.3635	373.37	87.2696	23.37	-0.80	2.42
29	41	600	35.49	38.72	7.8824	23234.57	4729.4526	20.36	**1.05**	0.69
30	38	50	4.58	60.24	13.1016	3011.79	655.0778	21.75	0.72	2.26
31	50	590	15.54	17.39	5.0843	10260.10	2999.7115	29.24	-0.50	-0.94
32	86	50	0.20	2.67	1.7246	133.36	86.2316	64.66	0.34	-2.32
33	82	595	1.10	1.21	0.8436	720.80	501.9608	69.64	**1.99**	4.38
34	67	25	0.07	1.80	0.6725	44.96	16.8117	37.39	0.04	-0.20
35	58	195	0.45	1.48	0.4260	288.32	83.0635	28.81	-0.23	2.92
36	75	10	0.03	1.75	0.8702	17.49	8.7022	49.77	**1.52**	3.10

[1]Significant values in **bold**

Table 1: Item variables

	Lab	Q	Contrib	Mean rate	SD	Mean total	SD	COV	Skew	Kurt	Detailed rate
Lab	1.00							0.36			-0.36
Q		1.00	0.55			0.51	0.59				
Contrib		0.54	1.00			0.99	0.95				0.47
Mean rate	-0.41			1.00	0.97						
SD	0.47	0.46		-0.68	1.00						
Mean total			0.72	0.42	-0.46	1.00	0.95				0.48
SD	0.47	0.46		-0.68	1.00	-0.46	1.00				0.42
COV	0.34							1.00	0.36		-0.66
Skew									1.00	0.65	
Kurt										1.00	
Detailed rate	-0.36		0.47	0.64	-0.52	0.68	-0.52				1.00

Table 2: Correlations

Estimators								
	1	2	3	4	5	6	7	8
Including outlier								
Slope	0.02	0.14	0.06	0.06	0.03	0.01	0.02	0.05
Calculated r	0.993	0.975	0.651	0.980	1.000	0.843	0.748	1.000
Crit r @ 95% conf	0.325	0.325	0.325	0.325	0.325	0.325	0.325	0.325
Crit r @ 99% conf	0.418	0.418	0.418	0.418	0.418	0.418	0.418	0.623
Excluding outlier								
Slope	0.02	0.01	0.10	0.04	0.03	0.00	0.03	-
Calculated r	0.923	0.061	0.541	0.768	0.995	0.184	0.583	-
Crit r @ 95% conf	0.330	0.330	0.330	0.300	0.330	0.330	0.330	-
Crit r @ 99% conf	0.424	0.424	0.424	0.424	0.424	0.424	0.424	-

Table 3: Summary of calculated and critical correlation coefficients for the two variables of unit rate and AA

	Sums of squares	Degrees of freedom	Mean square	F ratio	Probability
Between items	10753.4	35	307.2		
Within items	22557.1	216	104.4		
Between estimators	735.4	6	122.6	1.179	0.318
Residual	21822.4	210	103.9		
Total	33311.2	251			

Table 4: Components of variance analysis

Model	multiple r	(prob)	constant	(prob)	slope	(prob)
All sections						
Mean	0.675	0.000	-0.920	0.088	0.067	0.000
Outlier removed	0.365	0.000	-0.040	0.884	0.034	0.000
Total	0.026	ns				
Outlier removed	0.011	ns				
Work section 1						
Mean	0.829	0.000	-0.892	0.000	0.249	0.000
Total	0.045	ns				
Work section 2						
Mean	0.684	0.000	-3.267	0.069	0.071	0.000
Outlier removed	0.399	0.000	0.320	0.173	0.014	0.000
Total	0.094	0.392				
Outlier removed	0.043	0.710				
Work section 3						
Mean	0.780	0.000	0.026	0.682	0.023	0.000
Total	0.330	0.008	0.287	0.001	$0.265(10^{-6})$	0.008

Table 5: Regression of AA means/item totals on AA standard deviations by work section

Estimators								
	1	2	3	4	5	6	7	8
All items								
Calculated r	0.224	0.016	0.190	0.083	0.060	0.101	0.007	0.339
Crit r @ 95% conf	0.325	0.325	0.325	0.325	0.325	0.325	0.325	0.497
Crit r @ 99% conf	0.418	0.418	0.418	0.418	0.418	0.418	0.418	0.418
All items less max rate								
Calculated r	0.479	0.219	0.353	0.150	0.160	0.245	0.161	-
Crit r @ 95% conf	0.330	0.330	0.330	0.330	0.330	0.330	0.330	-
Crit r @ 99% conf	0.424	0.424	0.424	0.424	0.424	0.424	0.424	-

Table 6: Summary of calculated and critical correlation coefficients for the two variables of unit rate and coefficients of variation

	Sums of squares	**Degrees of freedom**	**Mean square**	**F ratio**	**Probability**
Between items	0.322	35	0.009		
Within items	1.250	216	0.006		
Between estimators	0.064	6	0.011	1.902	0.082
Residual	1.186	210	0.006		
Total	1.573	251			

Table 7: Components of variance analysis

Model	multiple r	(prob)	constant	(prob)	slope	(prob)
All sections						
Mean	0.004	0.948				
Outlier removed	0.122	0.050				
Total	0.087	0.158				
Outlier removed	0.086	0.164				
Work section 1						
Mean	0.201	0.028	0.053	0.000	0.002	0.028
Total	0.031	0.742				
Work section 2						
Mean	0.246	0.024	0.024	0.000	$3.88(10^{-5})$	0.024
Outlier removed	0.415	0.000	0.044	0.000	$3.28(10^{-5})$	0.000
Total	0.111	0.316				
Outlier removed	0.086	0.458				
Work section 3						
Mean	0.172	0.177				
Total	0.163	0.202				

Table 8: Regression of AA means/totals on coefficients of variation by work section

Estimators										
	1	2	3	4	5	6	7	8	Total	% of items
Coefficient of variation										
>0 and <2	11	7	10	7	3	25	34	1	98	36.7
>2 and <5	12	11	17	18	33	5			96	36.0
<5 and <10	10	10	8	9		1		14	52	19.5
>10	3	8	1	2		5	2		21	7.8
Total	36	36	36	36	36	36	36	15	267	100.0

Table 9: Range of AA coefficient of variation for estimators 1 to 8

Fig 1: Regression line of builders undertaking detailed analysis and item total

Fig 2: Variability of the total sum related to the number of items for contractors 1 to 8