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THE EFFECT OF CLIENT AND TYPE AND SIZE OF CONSTRUCTION WORK ON A CONTRACTOR'S BIDDING STRATEGY

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ABSTRACT

This paper offers a bidding strategy model for use by contractors as part of a more informed approach in selecting which contracts to bid for, and as a basis for determining the most appropriate mark-up level for various types and sizes of construction work and client types. Regression analysis is used in measuring a contractor's competitiveness between bids (by using the lowest bid / own bid ratio) and within bids (by using the lowest bid / cost estimate ratio) according to type and size of construction work and client type. The model was tested on a large and reputable Hong Kong contractor. This particular contractor's bidding behaviour was found to be largely unaffected by type of construction work but significantly affected by client type and size of construction work. Three quadratic models (regressing lowest bid / cost estimate on size of construction work) are also successfully developed for projects from the private sector, the Hong Kong Government and the Hong Kong Housing Authority respectively.

KEYWORDS: Bidding strategy, construction work type, construction work size, client, mark-up, competitiveness, regression analysis.

INTRODUCTION

A significant amount of construction work is let through competitive tendering. This typically involves a customised design being constructed with the roles of the client and contractor being contractually defined. Contracting may be defined as a service which is related to individual construction work packages, each one of which may be likened to a firm with a relatively short and finite life [1].

Contract bidding is a well established mechanism for achieving distribution of work to willing contractors and is concerned with contractors making strategic decisions in respect of (1) the selection of contracts to bid for; and (2) the bid levels necessary to secure them [2]. If a contractor opts to bid, the pricing of the bid normally comprises a two-stage formulation process consisting of a baseline cost estimate and subsequent mark-up [3] for e.g. overheads, profit and risk (Albeit an exception to the rule, 'mark-up' can in certain settings represent 'mark-down').

Contractor's bidding strategy is concerned with setting the mark-up level to a value that is likely to provide the best pay-off. The contractor 'must choose a price high enough to provide sufficient contribution to overheads and profits, yet low enough to ensure that a sufficient volume of work is actually obtained ... in an environment of considerable uncertainty about the behaviour of the competitors' [4].

Bid mark-up models have been considered extensively in the literature starting with Friedman's paper [5] who, in 1956, proposed using a probabilistic approach to determine the most appropriate mark-up level for a given contract. Smith [6] identified three approaches to bid modelling as being: (1) models based on probability theory; (2) econometric models; and (3) regression models. Carr and Sandall [7] suggested that regression modelling has many potential uses for contractors in a competitive bidding environment and used regression modelling to determine a contractor's optimum mark-up level.

The model offered in this paper does not focus on optimising contractor's mark-up, but on modelling the lowest bid / cost estimate ratio and regressing it against size of construction work, type of construction work and client type. Drew and Skitmore [8] used regression analysis to measure contractor competitiveness between bids (by using the lowest bid / bid ratio) according to type and size of construction work. This paper extends this former research by using a similar methodology to: (1) model competitiveness within a contractor's bid (by introducing the lowest bid / cost estimate ratio); and (2) consider the effect of client type on competitiveness in bidding. It should be noted that size of construction work is represented by the lowest bid price since this reflects, to some degree, both the size and complexity of the contract package.

BIDDING STRATEGY

The construction market within which contractors compete for work is seen by Newcombe [9] as being made up of a series of sectors, each requiring a different set of resources, skills and management expertise and comprise general contracting, civil engineering, speculative house building, property development, manufacture and supply of building products, plant and equipment hire. Langford and Male [10] identify that the market is made up of four main areas (namely building, civil engineering, repairs and maintenance and materials manufacturing). They go on to point out that these may be sub-divided into market sectors. For example, they state that the building market consists of housing, industrial and commercial markets. Lansley et al [11] suggest an alternative view, that is, with the exception of housing development, contractors do not consider the market in terms of sectors but in terms of the technologies required to execute project types.

Management theorists typically use the systems approach to model the behaviour of firms. Male [12,13] relates the construction bidding process to this approach. Male identifies that contractors define a strategic domain at the corporate strategy level with the domain establishing the market dimensions within which contractors plan to operate and compete for work. Contractors then make decisions on which contracts to bid for at the business strategy level. If opting to bid, the cost estimate is then formulated at the operational strategy level and fed back to the business strategy level where senior management then decides the appropriate level of mark-up at an adjudication meeting.

According to Skitmore [2], only bids derived from producing a detailed cost estimate and adding a realistic mark-up can be regarded as genuinely competitive. Other actions, such as obtaining a cover price, are merely procedural and being non *bona-fide*, it is less likely that the contractor will succeed in undertaking the work. Bids submitted to the client, therefore, may be classified as being either serious or non-serious bids. Other classifications include misconstrued bids (errors contained) or suicidally low bids (well below cost as characterised by contractors experiencing cash flow problems)[14].

Contractors adopt various strategies to enhance their chances of winning work. Fine [15] has identified several strategies including random bidding when work levels are low, selective bidding and severely competitive bidding with claim back options within the limits of the contract. Stone [16] has also suggested that some firms accept lower standards of work than others and that there are differences in efficiency and therefore, cost.

Factors that affect the bidding decision are shown to fall into three main categories, namely job characteristics, economic environment and competition condition [7]. Based on similar rationale, factors influencing bidding behaviour were grouped by Drew and Skitmore [17] into those affecting: (1) the behaviour of contractors as a group (eg. market conditions, number and identity of competitors); (2) individual contractor behaviour (eg. contractor size, work and tenders in hand, availability of staff); and (3) behaviour toward the characteristics of the contract (eg. type and size of construction work, client, location).

Flanagan and Norman [18] identified that bidding behaviour, in general terms, is likely to be affected by the following five major factors:

(1) size and value of the project, and construction and managerial complexity required to complete it;
(2) regional market conditions;
(3) current and projected workload of the tenderer;
(4) type of client; and
(5) type of project.

The bid model offered in this paper shows the effect on bidding strategy of three of these factors, namely size and value of project, type of client and type of project. These three factors have all been identified as being important in separate surveys undertaken by Eastham [19], Shash [20] and Teo et al [21]. In another survey, Odesote and Fellows [22] found that 75% of respondents identified client related factors and type of work as being the most important with the value of project ranked third.

Flanagan and Norman [23] examined the bidding performance of small, medium and large contractors in respect of type and size of construction work. They found that when bidding (1) the small contractor considered both the type and size of construction work, (2) the large contractor was more successful on bidding for large contracts and (3) the medium contractors' competitiveness was not related to type and size of construction work. This study suggests that the competitiveness of competing contractors towards the type and size of construction work differs to varying degrees.

In developing this notion, Drew and Skitmore [8] used regression analysis to model competitiveness between bids of competing contractors. Using data collected from tender reports they modelled the competitiveness behaviour of 15 contractors toward five different types of construction work. It was found that the 15 contractors' competitiveness did not differ significantly between some types. The original five types were, therefore, regrouped into three types on the basis of the contractors' competitiveness. Two of these comprised mainly smaller contracts and the other larger contracts. Some of the contractors were found to display the same behaviour as those in the Flanagan and Norman study. In addition, it was found that the most competitive contractors had preferred contract sizes for either smaller or larger contracts and that one contractor was more competitive on smaller contracts. They also found that competitiveness differences were greater for different sizes of construction work than for different types of construction work. In other words, size of construction work appeared to influence competitiveness more than type of construction work.

MODELLING AND MEASURING COMPETITIVENESS IN BIDDING

Much of bidding research is concerned with modelling bidding behaviour by considering competitiveness relationships. Competitiveness in bidding can be modelled by analysing: (1) entire bid distributions; (2) competitiveness within bids; (3) competitiveness between bids for either a single or series of construction contracts.

For most practical purposes it is sufficient to consider bids in relation to a baseline. Baselines include the designer's estimate, contractor's cost estimate and the mean, median or lowest of the bids entered for a particular contract. Of these, the lowest bid has the advantage that at the time of bidding it represents the maximum level of competitiveness. By using the lowest bid as a baseline, other bids and cost estimates can be expressed as a percentage or ratio to this lowest bid baseline. Using the maximum value of competitiveness means that all competitiveness values will be on an absolute scale and easier to understand. Beeston [24] is of the opinion that it should be practical to improve bidding performance by studying one's own results in relation to the winning bid which can normally be assumed to be the lowest bid submitted. It is worth noting that this opinion is given even though the lowest bid may, on occasion, consist of a cover price, be misconceived or contain errors.

A commonly used measure of competitiveness between bids is to express each bid as a percentage above the lowest bid ie.

$$BCP = 100(x - x_{(1)})/x_{(1)} \qquad \text{(Equation 1)}$$

where

BCP = bid competitiveness percentage

x = contractor's bid

$x_{(1)}$ = value of lowest bid entered for the contract.

Lower percentage values indicate greater competitiveness and vice versa with minimum and maximum competitiveness being constrained respectively between infinity and zero. The resulting competitiveness indices can be aggregated over a series of contracts to produce an average competitiveness index for each contractor. Consistency in bidding can be gauged from the resultant standard deviation.

By substituting bid for cost estimate, contractors can also determine the competitiveness relationship between their cost estimate and the lowest bid i.e.:

$$CECP = 100(x - x_{(1)})/x_{(1)} \qquad \text{(Equation 2)}$$

where

CECP = cost estimate competitiveness percentage

x = contractor's cost estimate

$x_{(1)}$ = value of lowest bid entered for the contract.

Larger negative percentage values indicate greater competitiveness. Positive values indicate that there are competitors who are able to achieve a bid lower than the contractor's cost estimate.

In measuring competitiveness between bids, Drew and Skitmore [8] expressed competitiveness as a ratio rather than a percentage, i.e.:

$BCR = x_{(1)}/x$ (Equation 3)

where

BCR = bid competitiveness ratio

x = contractor's bid

$x_{(1)}$ = value of lowest bid entered for the contract.

Maximum and minimum competitiveness are respectively constrained between one and zero. They identified a number of advantages in using this measure. This includes: computational ease; the logarithmic scale makes competitiveness differences more pronounced nearer unity (the end of the scale which is likely to be of most interest); and adaptability to transformation.

Relationships between a contractor's cost estimate and the lowest bid can also be expressed as a ratio, i.e.:

$CECR = x_{(1)}/x$ (Equation 4)

where

CECR = cost estimate competitiveness ratio

x = contractor's cost estimate

$x_{(1)}$ = value of lowest bid entered for the contract.

Values less than unity indicate that there are competitors who are able to achieve a bid lower than the contractor's cost estimate and vice versa. This has the advantage over the percentage measure in that there are no negative values. It can, therefore, be used in regression modelling.

DEVELOPMENT OF THE REGRESSION MODEL

Competitiveness, expressed in the form of the foregoing bid and cost estimate ratios (i.e. Equations 3,4) can be taken to be the dependent variables. Size of construction work, a quantitative independent variable, has been expressed in terms of contract value. A quadratic term for this variable is added to allow the regression line to better reflect possible economies of scale between size of construction work and size of contractor.

Relationships between the foregoing competitiveness measures and size of construction work can be observed by plotting the value of bids and cost estimates entered in past competitions against the respective bid and cost estimate competitiveness ratios (ie. Equations 3,4). Curvilinear regression analysis can be used to determine the lines of best fit for both the bid competitiveness and cost estimate competitiveness (eg. Figure 1).

Assuming these regression lines represent a contractor's true competitiveness / construction work size relationship, then the line derived from values appertaining to the bid ratio (ie. Equation 3) indicates that the contractor is most competitive at the peak (ie. where the equation is closest to unity). Similarly, in respect of the cost estimate ratio (ie. Equation 4) the contractor is also most competitive at the peak of the regression line.

Depending on the competitiveness of the contractor, the cost estimate regression line may intersect the x-axis. If the cost estimate regression line cuts through the x-axis, the points of intersection are where the cost estimate equals the lowest bid. In between these points indicates the construction work size range for which the contractor is able to generate cost estimates lower than the lowest bid. A crude measure of a contractor's competitiveness over other competitors can be gauged by considering the hatched enveloped area between the regression line and the x-axis. The larger the hatched enveloped area the greater the contractor's competitive advantage.

The predicted mark-up needed to produce the lowest bidder can be obtained by finding the vertical difference between the x-axis (ie. the lowest bid line) and the regression line representing the cost estimate ratio. Similarly, the contractor's bid competitiveness relative to the lowest bid can be found by observing the difference between the x-axis of the graph and the bid ratio.

Type of client and construction work are both categorical qualitative variables. A single prediction equation for each client and type of work can be found through the standard regression procedure of using dummy variables.

Drew and Skitmore [8] used a model building approach to determine the best contractor competitiveness model for size and type of construction work. 22 candidate models comprising different chunks of predictor variables were developed for the independent variables of contractor identity, type of construction work and size of construction work. This approach is replicated in this paper, with the independent variable client type being substituted into the equation in the place of contractor identity and with the cost estimate ratio (ie. Equation 4) being introduced as a measure of competitiveness.

DATA SAMPLE

The data sample, comprising 100 consecutive bidding attempts together with corresponding cost estimates and lowest bid values, were collected from a large reputable Hong Kong contractor for the period July 1991 to May 1994. Information was also obtained on the type of construction work (according to the CI/Sfb classification system [25]) and client type based on a classification system proposed by Masterman [26].

Type of construction work is classified as follows:

(1) Civil Engineering Facilities (e.g. road/air/water transport facilities);
(2) Industrial Facilities (e.g. factories);
(3) Administrative Facilities (e.g. offices, law courts);
(4) Health Facilities (e.g. hospitals, clinics);
(5) Recreational Facilities (e.g. cinemas, sports stadia);
(6) Religious Facilities (e.g. churches, temples);
(7) Educational, scientific facilities (e.g. schools, libraries);
(8) Residential Facilities (e.g. housing, hostels); and
(9) Common Facilities (e.g. public toilets, storage).

Client type is classified as follows:

(1) Government;

(2) Housing Authority;

(3) Other public sector clients;

(4) Large developers;

(5) Large industrial, commercial and retailing organisations;

(6) Medium and small industrial, commercial and retailing organisations; and

(7) Other private sector clients.

The bids, cost estimates and lowest bid values were updated to a common base date (ie. May 1994) using tender price indices published by Levett and Bailey [27].

ANALYSIS

The following analysis is reported in two parts. Descriptive statistics according to client, type and size of construction work are reported in the first part of the analysis. This is used as a basis for developing the regression model in the second part of the analysis.

It should also be noted that although the competitiveness ratio measures (ie. Equations 3 and 4) could be used throughout the entire analysis, the competitiveness percentage measures (ie. Equations 1 and 2) have been used in the descriptives analysis. This is primarily for the reader’s benefit since competitiveness relationships between the cost estimate, bid and lowest bid are more commonly expressed in percentage terms. The ratio competitiveness measures (ie. Equations 3 and 4) have therefore been confined to the regression analysis.

DESCRIPTIVES ANALYSIS

The sample of data shows that this contractor submitted bids with an overall average value of HK$336 million, ranging from HK$1 million to HK$3,349 million dollars. This very wide range of bid values tends to suggest that this contractor has no particular bid policy on upper or lower bid limits. The range of mark-ups applied to the cost estimates varied between -8% to +50% with an average of +7.55%. In terms of mark-up it appears that on some contracts, at least, this contractor is willing to bid very competitively, whilst on others this contractor appears to have submitted 'non-serious' bids. The bid percentage (ie. Equation 1) is on average 9.03% above the lowest bid baseline. The cost estimate percentage (ie. Equation 2) is on average 1.65% above the lowest bid baseline. In other words, the contractor's competitors were, on average, able to submit bids 1.65% lower than the contractor's own cost estimates signifying that, perhaps, this particular contractor is not so competitive.

Further evidence of the lack of competitiveness can be found by observing the number of times that the contractor was the lowest bidder. Out of 100 bidding attempts this contractor was the lowest bidder on only four occasions; twice each in the public and private sectors. This seemingly low rate can partly be explained because large numbers of contractors are often encouraged to bid in Hong Kong. (Two separate studies identified that the average numbers of contractors competing per contract were 13 in the public sector [8] and 9 in the private sector [28]). The contractor was subsequently successful in winning a total of eight out of the 100 contracts; two in the public sector (for which the contractor was the lowest bidder) and six in the private sector. The higher success rate in the private sector is likely to be because clients prefer large contractors to small contractors (Drew and Skitmore [28] found that private sector clients preferred to enter into contracts with larger size contractors even though they did not submit the lowest bid price).

Table 1 shows the sample bid data broken down according to type of construction work. It can be seen that this contractor has bid for every type of construction work and that the average mark-up of 14.47% for civil engineering work (i.e. construction work type 1) is approximately double that for building work (i.e. construction work types 2 - 9); which vary between 3.81 to 8.31%. The higher mark-up percentage is probably indicative of the greater risk associated with civil engineering work. If types 2 and 6 are ignored (because they contain very few bidding attempts) it would seem that this contractor is most competitive for civil engineering work. This is reflected in both the bid percentage and cost estimate percentage above the lowest bid. It can also be clearly seen that this contractor is most uncompetitive with work types 4 and 5. With the exception of types 1, 4 and 5, the cost estimate percentage varies very little on the remaining types, fluctuating between -2.22% and 2.94%.

Table 2 shows the breakdown of bidding attempts according to client type and client sector (ie. public / private sector). With the exception of developer (ie. client type 4), this contractor has bid for every client type and has a reasonably balanced proportion of bids in both the public sector (comprising client types 1-3) and private sector (comprising client types 5-7). It can be seen that the cost estimate percentages (relative to lowest bid) for the private sector are all negative while those for the public sector are all positive. In cost estimate terms, it therefore seems that this contractor is more competitive when bidding for private sector work. This is also reflected in the bid percentages above the lowest bid. It appears, however, that the contractor may not be fully aware of the extent of the difference given that the mark-up percentages are only marginally higher in the private sector when compared to those in the public sector.

Table 3 shows the type of construction work broken down into public and private sectors according to CI/Sfb classification and also according to whether the work is civil engineering (ie. construction type 1), building (ie. construction types 2-7 and 9) or housing (ie. construction type 8). The competitiveness difference between public and private sector work can also be clearly seen in this table with the contractor managing to obtain a negative cost estimating percentage for almost every type of construction work in the private sector. It can also be seen that the contractor is most competitive in terms of cost estimate percentages for both public sector and private sector civil engineering work and in terms of bid percentage for public sector civil engineering work.

REGRESSION ANALYSIS

A. A preliminary study – the chunk-wise regression

Although only three independent factors are considered in this study for the competitiveness difference of the contractor, due to the categorical nature of two factors, which requires the use of dummy variables for each level of these factors, the total number of independent variables considered is equal to 16 (9-1 dummy variables for work type, 7-1 dummy variables for client types and x and x^2 for size of construction work). When the interactions of these variables are included, the model will include a large number of terms. In order to reduce the number of models to be considered, chunk-wise regression analysis is used [29] as a preliminary study of the effects and interactions of these factors. The chunkwise technique for variable selection has some important advantages over single variable selection techniques. Apart from reducing the number of models to be considered, the chunkwise method allows sets of variables for which there is prior scientific knowledge and preferences, to be incorporated into the analysis. The sequence of predictor variables can also be controlled. This permits the influence of each chunk to be measured rather than relying on a technique such as stepwise regression in which all theoretical considerations are removed. Klienbaum et al [29] point out that in many situations such testing for chunk significance can be more effective and reliable than testing variables one at a time (as is the case with stepwise regression).

Client sectors (private/public), rather than client types, are considered first for which two regression models have been developed. The first model focuses on the narrower CI/Sfb construction work type classification while the second on the broader construction work sector classification of civil engineering, building and housing work. By developing both models comparisons can be made on whether work type or work sector is more dominant in the contractor’s bidding behaviour.

Figure 2 shows the 22 proposed candidate models for the narrower CI/Sfb construction work type classification. It can be seen that a chunk of predictor variables is required for each independent variable (ie. S, T, P). Two-way interactions (ie. ST, SP and TP) and three-way interactions (ie. STP) are also considered. The candidate models for the construction work sector classification are based on exactly the same rationale except that the broader construction work sector variable is substituted in place of the narrower CI/Sfb construction work type variable.

Given that quadratic regression models, such as these, require a minimum of three bidding attempts for each categorical variable (see [30]), it can be seen from Table 3 that there are insufficient bidding attempts on construction work types 2, 4, 5, 6 and 7. Only data appertaining to types 1, 3, 8 and 9 has, therefore, been included in the narrower construction work type model while the whole data set has been included in the broader construction work sector model.

With the candidate models in place, the next stage of the analysis is to determine the best model by using a forward chunk-wise sequential variable selection algorithm based on the F-test for both the construction work type and construction work sector models with the bid ratio (ie. Equation 3) and cost estimate ratio (ie. Equation 4) as the dependent variables.

Table 4 compares the candidate model statistics with the cost estimate ratio as the dependent variable for both the narrower construction work type and broader construction work sector models. In considering the model utility statistics overall, it can be seen that the low adjusted R^2 statistics indicate that only a relatively small percentage of the variation is attributable to, or explained by, the independent variable x. In other words, the three independent variables appear to explain relatively little about the competitiveness behaviour of this contractor. Having said that, nearly all of the candidate models are, however, still statistically useful as indicated by the global F test probability value (ie. Signif F) being less than 5%. In comparing the model utility statistics between the construction work type and construction work sector models, there appears to be very little to choose between them, indicating that this contractors' bidding behaviour toward work type or work sector appears to be roughly the same.

Table 5 shows a similar comparison with the bid ratio as the dependent variable. The model utility statistics are comparatively poor to those in Table 4 with only candidate model 3 for the construction work sector being statistically useful with a significant F value of 0.0282 and a corresponding adjusted R^2 value of 0.06136. It seems, therefore, that the cost estimate ratio (ie. Equation 3) is a better competitiveness predictor than the bid ratio (ie. Equation 4).

Using a forward chunkwise sequential variable selection algorithm based on the F-test (see e.g. [29,30]) to determine the best model, it was found that model 3 is the best model according to both ratio measures (ie. for Equations 3 and 4) and for both construction work type and construction work sector. This lower order model only contains the construction work size (S) and client sector (P) main effects, indicating that this contractor's competitiveness is not influenced by work sector and is also not influenced by size-client sector (SP) interaction effects.

B. Client-Type Specific Regression Analysis

The foregoing analysis suggests that work size and client sector are important factors affecting the competitiveness of the contractor. However, the adjusted R^2 values even for the best model (model 3) are very low. It is suspected that one single regression model may not be suitable for all the client types and the effect of work size may be different for different client types. Although model 3 developed in the chunk-wise regression analysis is a model with no interactions, indicating that the effects of work size on the competitiveness of the contractor are not significantly different among public and private sector clients, the non-significance of this interaction term may simply be due to the use of two client sectors instead of the six client types. It is still possible that the effect of work size would be different among the six different client types. In order to improve the fitting of the models, separate models regressing on work size and work size squared are therefore developed for different client types for further investigation of the effect of work size.

In that work type has not been found to be significant, for different client types, the only independent factor considered in this analysis is work size (and its squared term). The cost estimate of the project is used as indicator of work size. As described earlier, the bids submitted by this contractor range between HK$1 million to HK$3,349 million with an average value of HK$336 million, the distribution of the corresponding cost estimates therefore exhibits a long right-hand tailed pattern. One way to scale (normalize) the cost estimate data is to take the logarithmic transformation. Hence, in the development of regression models, both the cost estimate and its logarithmic transformation are considered as potential candidates for the independent variables.

The first step in the analysis is to divide the 100 cases into two groups with 43 cases for the private client sector and 57 cases for the public client sector. For the private sector (client types 5, 6, and 7), the independent factor log-cost and its squared term are found to provide valuable insight to the variation in competitiveness of the contractor with R^2 at 0.4598 (adjusted R^2=0.4328). The regression model is:

$$CECR = X_{(1)}/X_{CP} = 1.2814 - 0.1017*\text{log-cost} + 0.00915*(\text{log-cost})^2$$

If the log-cost is standardized by its sample mean of 4.5709 and sample standard deviation of 1.6899, the regression model in terms of the standardized log-cost is:

$$CECR = 1.007827 - 0.03043*\text{standarized log-cost} + 0.02617*(\text{standardized log-cost})^2$$

Hence, for clients from the private sector, the contractor may use one single regression model to evaluate its competitiveness performance with respect to different work size according to the logarithmic value of its cost estimate of the project. For example, if the contractor estimates that the cost of a new project for a private client is HK$50 million, its corresponding measure of competitiveness, CECR, is 1.0235. This model is quadratic and has a minimum at HK$259 million indicating that for private clients, this contractor is in general performing better either for small size or large size projects.

As for the public sector, no single model can be found to describe satisfactorily the variations in the index of competitiveness of the client. Separate regression models are needed for individual client types.

For government projects, there are 21 reasonable cases (case 41 is suspected as an outlier and is not included in the analysis). The cost estimate and its squared term are found to be significant factors for the regression model. The corresponding R^2 is 0.3298 with adjusted R^2 equals 0.2553. The quadratic regression model is:

$$CECR = X_{(1)}/X_{CP} = 1.0045 + 0.000116*\text{cost} - 6.513\text{x}10^{-7}*\text{cost}^2$$

If the cost is standardized by its sample mean of 259.5643 and sample standard deviation of 226.7966, the regression model in terms of the standardized cost is

$$CECR = 0.9906 – 0.0505*standarized\ cost - 0.0335*(standardized\ cost)^2$$

This regression model has a maximum at 89.05 indicating that for Hong Kong Government projects, this contractor is most effective for projects costing around HK$90 million.

For projects from the Housing Authority (a government subsidised organization), there are nine reasonable observations (case 44 is an outlier and is not included in the analysis). A quadratic model using the factor “cost” provides a very good fit to the data. The R^2 is 0.7148 and the adjusted R^2 is 0.6197. The model is:

$$CECR = X_{(1)}/X_{CP} = 1.0175 + 0.000201*cost – 5.0864x10^{-7}*cost^2$$

If the cost is standardized by its sample mean of 454.3022 and sample standard deviation of 171.7691, the regression model in terms of the standardized cost is:

$$CECR = 1.003734 – 0.044912*standarized\ cost - 0.015*(standardized\ cost)^2$$

This quadratic regression model has a maximum at 195.5857 indicating that for projects from the Housing Authority, the contractor is most effective for projects costing about HK$200 million.

There are 25 other cases belonging to the public sector that cannot be grouped under government or Housing Authority. No regression model could provide satisfactory explanation of the variation in the level of competitiveness among the projects in this group. The diversity of client types in this group could account for the lack of a common coefficient for the effect of work size.

Figure 3 shows the index of competitiveness, CECR= $X_{(1)}/X_{CP}$, as functions of cost estimate of projects from the private sector, the Government and the Housing Authority respectively. It can be seen that this contractor performs well for projects of size between 100 to 200 HK$ millions from both government and housing authority, but it only does well for projects of size of less than 100 HK$ million from private sector.

CONCLUSIONS

Three important factors influencing contractor bidding behaviour have been identified in the literature as (1) type of client, (2) type of construction work and (3) size of construction work. The competitiveness effect these three variables have had on one large Hong Kong contractor's bidding strategy has been studied in this paper using regression analysis.

In considering the contractor’s bidding behaviour overall, it seems that the contractor has a largely unfocussed strategic bidding domain - the contractor having submitted bids for many different types of work, over a very wide range of contract sizes and to many types of client. This can be explained in part by the pressures of competition in Hong Kong, with large numbers of contractors often being encouraged to bid, make it difficult for many contractors to develop a clear and decisive strategy. From discussions with the contractor it appears that reputation is also an important factor in getting work, particularly in the private sector.

The contractor is also not very competitive generally . Out of one hundred bidding attempts the contractor was only the lowest bidder on four occasions; two in the public sector and two in the private sector. In addition, the cost estimate values average only 1.65% above the lowest bid values, with many competitors’ bids below the contractor’s cost estimate. In terms of specific types of construction work, the initial descriptive analysis indicated this contractor to be more competitive toward civil engineering work and less competitive toward health and recreational facilities. Competitiveness differences between public sector and private sector clients however were comparatively small.

In the development of a preliminary regression model to identify the influential factors, a forward chunkwise sequential variable algorithm based on the F-test showed candidate model 3 to be the best model for both the bid and cost estimate ratios and for both construction work type and construction work sector. This lower order model contains only the construction work size (S) and client sector (P) main effects, indicating that this contractor's competitiveness is not influenced by work size or work sector (T), nor by size-client sector (SP) interaction effects. However, when client sector and work size were used to develop a single regression model for index of competitiveness, the adjusted R^2 values were very low. Client-type specific regression models were therefore developed for different client types. The results show that the index of competitiveness, CECR= $X_{(1)}/X_{CP}$, of projects from the private sector, the Government and the Housing Authority are quadratic functions of the cost estimates of the project respectively. This showed that the contractor performs well for projects of size between 100 to 200 HK$ millions from both the Hong Kong Government and Hong Kong Housing Authority, but it only does well for projects of size of less than 100 HK$ millions from the private sector.

From a methodological viewpoint, both the bid ratio and cost estimate ratio regression models were found to be statistically significant in predicting competitiveness, although the cost estimate ratio was a better predictor of bidding behaviour than the bid ratio - probably because mark-up variability (in submitting serious and non-serious bids) is reflected in the latter measure.

In contrast with most published work on this topic, the research described in this paper is of a purely empirical nature. The intention is to identify patterns of bidding behaviour as an aid to greater understanding and possible future exploitation by participants. Many standard bid strategy models are highly prescriptive, relying on the rather questionable presumption of profit maximisation, (statistically) intercontractually and intertemporally consistent competitors, and focusing on the mathematical derivation of optimal mark-ups. Clearly it difficult to develop realistic models that capture the complexity and uncertainty of the full construction contract bidding situation, which is perhaps why many contractors do not show much interest in such models. The analysis described in this paper reveals some of the more salient aspects of the complexities involved, in the form of type and size of the contract project and type of participating client organisation, for one contractor operating in the Hong Kong region. A similar analysis of other contractors, is likely to reveal further aspects and with different degrees of emphases. In this way, it can be conjectured that the true nature of the competitiveness of construction contractors will be revealed and one that will include the relative efficiencies of the contractors involved and how these are related to contract and client characteristics as well as strategies for pricing.

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