ENHANCING BID DECISION MAKING IN THE CONSTRUCTION INDUSTRY: A NEW MULTI-CRITERIA PROSPECT MODEL

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Abstract

In the construction industry, government agencies and private sector clients typically adopt competitive bidding to determine contract awards. Two critical decisions that bidders face in competitive bidding include those regarding (1) whether or not to submit a bid and (2) what markup scale to use on the submitted bid (if the answer to the first is in the affirmative). This paper proposes a Multi-Criteria Prospect Model for Bidding Decision (BD-MCPM) to assist contractors to make these two decisions. A Vietnam bid case was used to validate the efficacy of BD-MCPM. Results indicate that the proposed BD-MCPM can effectively assist primary decision makers (PDMs) to select bids on which their firm should bid and to establish optimal markup scales.

KEYWORDS: Bidding Decision Making, Multi-Criteria Prospect Model, Cumulative Prospect Theory, Fuzzy Preference Relations.

INTRODUCTION

In the construction industry, contractors typically earn construction contracts through either direct negotiation or competitive bidding. Government agencies and private sector clients most often employ competitive bidding, which commonly adopts lowest bid pricing as the main award criterion. The bid price usually consists of the cost of construction plus a markup;

the latter being typically calculated as a certain percentage of construction costs. Markup size correlates positively with earned profit - the primary motivator for a contractor to win and execute a contract (Dikmen et al. 2007). Research into competitive bidding strategy models has been conducted since the 1950s (Friedman, 1956). Despite the large number of competitive bidding strategy models developed, few have been applied in practice. This is due primarily to their failure to address practical construction contractor needs (Hegazy et al., 1995; Shash, 1995). Therefore, there is a perceived need for models designed in line with actual construction contractor practices. In the bid process, once a bid determination has been made, the next step is to select an appropriate markup (Egemen et al. 2008). A successful contractor is the one that selects the most optimal bid markup that secures both the contract and contract profitability (Shash et al. 1992). Bid markup decisions currently follow no accepted standards or formal procedures, but, rather, consider contractor experience, intuition, and personal preferences, none of which are conducive to building an effective approach to achieve an optimal bid markup (Chua et al. 2000).

Cumulative prospect theory was proposed by Tversky et al. (1992). Diverging from classical theory, CPT adopted a concave-shaped utility function (UF) for gains, convex-shaped UF for losses, and an inverse S-shaped probability weighting function (PWF) to describe individual preferences between risky prospects. Wakker et al. (1996) proposed the trade-off (TO) method to elicit a subject's UF. Many studies (Wu et al., 1996; Gonzalez et al., 1999) have since worked to elicit the PWF for particular subjects. Abdellaoui (2000) and Bleichrodt et al. (2000) used TO method concepts to elicit the PWF of their respective subjects. Abdellaoui's study was further applied successfully to medical decision making.

Determining the relative weight of influential factors is important in multi-criteria decision making (MCDM). Fuzzy Preference Relations (FPR) is a useful tool to express the uncertain preference information of evaluators (experts) and define relative weights of influential factors. Significant attention has been given to fuzzy preference relations in recent studies (Chiclana et al., 2003; Herrera-Viedma et al., 2004; Xu et al., 2005). Wang et al. (2007) adopted FPR to forecast the probability of successful knowledge management.

This research combined FPR, CPT and MCDM to propose a Multi-Criteria Prospect Model for Bid Decision Making (BD-MCPM) to help construction company decision makers derive optimal bid decisions. The proposed model incorporates three phases. Phase I identifies factors that affect bidding decisions (i.e., bid / no bid, markup scale); Phase II introduces FPR to determine bid / no bid; and Phase III uses FPR and CPT to calculate CPT values for a given markup scale, then selects the markup scale with the highest CPT value.

LITERATURE REVIEW

Fuzzy Preference Relationships

Most decision processes are based on preference relations (PR), the most common representation of information in decision making. In PR, an expert assigns a value to each pair of alternatives that reflects the degree of preference for a first alternative over a second. Many important decision models have been developed using mainly two preference relation types, namely (1) Multiplicative Preference Relations (MPR) and (2) Fuzzy Preference Relations (FPR). A MPR on a set of alternatives X is represented by matrix A. Matrix A is usually assumed multiplicative reciprocal $A = [a_{ij}] \subset X \times X$, $a_{ij} \in [1/9,\ 9]$ and $a_{ij} \cdot a_{ji} = 1$ for $i, j \in \{1,\ \ldots,\ \ n\}$, where an a_{ij} at 9 denotes that x_i is preferred absolutely to x_j and a value at 1 represents no difference in preference between x_i and x_j. A FPR on a set of alternatives X is represented by a matrix B. Matrix B is a fuzzy set on product set $X\times X$ that is characterized by membership function μ_B: $X\times X\rightarrow[0,1]$. Therefore, $B = [b_{ij}]$ and $b_{ij} = \mu_B(x_i, x_j)$ for $i, j \in \{1,\ \ldots,\ \ n\}$, where μ_B is a membership function and b_{ij} is the preference ratio of the alternative x_i over x_j. A b_{ij} at 0.5 denotes that x_i and x_j are indifferent, and a b_{ij} at 1 represents that x_i is preferred absolutely to x_j. Matrix A can be transferred into matrix B using transform equation $b_{ij} = \left(1 + log_9\, a_{ij}\right)/2$. The relative weights w_i for all alternative i can be obtained using $w_i = \sum_j b_{ij} \Big/ \sum_i \sum_j b_{ij}$.

Cumulative Prospect Theory

Consider a prospect X with outcomes $x_1 \le \ldots \le x_k \le 0 \le x_{k+1} \le \ldots \le x_n$ that are associated with probabilities $p_1, \cdots, p_k, p_{k+1}, \cdots, p_n$. Cumulative prospect theory predicts that people will choose prospects based on the value generated by $V_{CPT}(X) = \sum_{i=1}^{k} \pi_i \lambda v(x_i) + \sum_{j=k+1}^{n} \pi_j v(x_j)$, where $v(x)$ is the utility function, $\lambda > 0$ is a loss-aversion parameter, and π represents decision weights calculated based on "cumulative" probabilities p_i associated with outcomes x_i. Decision weights employed in CPT are obtained by $\pi_i = \sum_{j=1}^{i} w^-(p_j) - \sum_{j=1}^{i-1} w^-(p_j)$ for $2 \le i \le k$, $\pi_i = \sum_{j=1}^{n} w^+(p_j) - \sum_{j=1}^{n} w^+(p_j)$ for $k+1 \le i \le n-1$ and the boundary $\pi_1 = w^-(p_1)$ $\pi_n = w^+(p_n)$. The probability weighting function w^+ represents gains and probability weighting function w^- represents losses.

CONSTRUCTING A MULTI-CRITERIA PROSPECT MODEL FOR BIDDING DECISIONS

Multi-Criteria Prospect Model for Bidding Decision Making

This study adopted BD-MCPM, which combined FPR and CPT, to model the bidding decision process, as shown in Figure 1.

Phase I – Preparation

The bidding decision process generates two decisions, namely (1) whether to submit a bid (bid / no bid) and (2)_if bid, the optimal markup scale to use on the submitted bid (Egemen et al., 2008). The objective of Phase 1 is to identify the key factors affecting the two aforementioned decisions, and, based on such factors, collect and organize relevant project data / information.

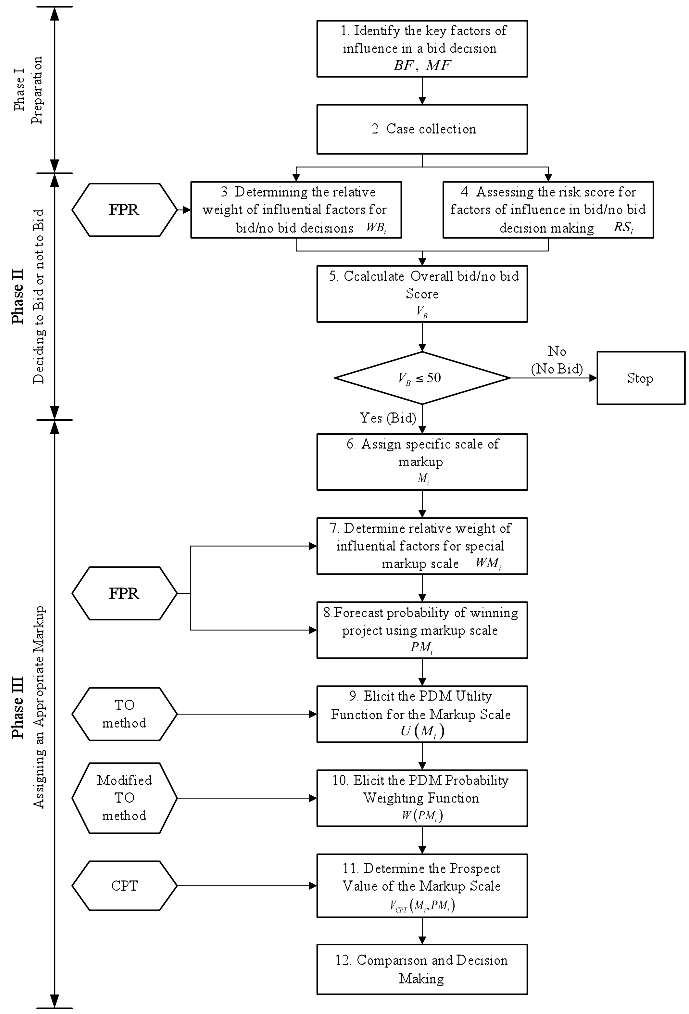

Figure 1: BD-MCPM Flowchart

Identify key factors of influence in a bid decision

Many studies designed to identify key factors of influence on bidding decisions have been conducted in recent years. Table 1 shows such factors at work on the decision between bid / no bid. Factors noted were chosen based on frequency of reference in the literature and attribution by local contractors (who were surveyed for this study using questionnaires).

Table 1: Key factors of influence on the "bid/no bid" decision

Category	Inferential Factor	Factor
Client	Relationship with Client	BF_6
Project	Project Size	BF_3
	Project Complexity	BF_7
Resources	Experience in Similar Project	BF_2
	Availability of Qualified / Experienced Staff	BF_8
Contract	Contractual Conditions	BF_4
Company	Current Workload	BF_5
Competitors	Number of Competitors	BF_9
Financial	Expected Profitability	BF_1
Risk	Expected risk	BF_{10}

Similarly, Table 2 shows the eight key factors identified in the literature as affecting markup decisions.

Table 2: Key factors of influence on the "markup scale" decision

Category	Inferential Factor	Factor
Project	Project Size	MF_5
Resources	Experience in Similar Project	MF_6
Company	Need for Work	MF_1
	Current Workload	MF_3
Competitors	Number of Competitors	MF_4
Financial	Expected Profitability	MF_8
Market	Overall Economy	MF_7
Risk	Expected Risk	MF_2

Collect case data

The BD-MCPM model was applied to case studies to demonstrate the potential effectiveness of the approach in practice. Table 3 presents a summary of data collected on three actual projects.

Table 3: Case study data

Item	Case 1	Case 2	Case 3
Owner	Housing and Urban Development Corporation (HUD)	Hanoi City People's Committee	Infrastructure Development and Construction Corporation (LICOGI)
Project	Housing project	Housing project	Housing project
	2 units - 14 floors and 21 floor	1 unit - 21 floor	2 units - 14 floors and 17 floor
	Total Floor area 21960m^2	Total Floor area 19950m^2	Total Floor area 19558 m^2
	Basement area 1588m^2	Basement area 1800m^2	Basement area 1500m^2
Location	Hanoi, Vietnam	Hanoi, Vietnam	Haiphong, Vietnam
Estimated cost	Approx. US $17,954,000	Approx. US $4,228,000	Approx. US$9,735,000
Total duration	30 months	18 months	24 months
Bidding system	Open competitive bid	Open competitive bid	Open competitive bid
Fund	Self, customer mobilization fund, Agri-Bank	Self (government)	Self, government, Viet Com Bank
Contract type	Lump sum	Lump sum	Lump sum
Payment methods	Local currency (VND)	Local currency (VND)	Local currency (VND)
Timing of payments	2.5 months	2 months	2 months
Prior project markup scale	Common markup 3-6%	Common markup 3-6%	Common markup 3-6%
	Best case 20% gain	Best case 20% gain	Best case 20% gain
	Worst case 15% loss	Worst case 15% loss	Worst case 15% loss

Phase II – Deciding to Bid or not to Bid

The goal of Phase II is to make a decision whether or not to bid on a particular project. Once a bid / no bid score has been obtained by assessing relative weights and risk scores for the ten key factors that affect the bid / no bid decision, it may be applied to bid / no bid decision making.

Determining the relative weights of factors of influence on bid/no bid decision making

This study used nine linguistic terms {AM, VM, SM, WM, EQ, WL, SL, VL, AL} associated with real numbers {5, 4, 3, 2, 1, 1/2, 1/3, 1/4, 1/5} to compare corresponding neighboring factors. Using both a questionnaire survey and interviews, evaluators adopted the 9 linguistic terms to assess the relative importance intensity for of the two adjoining factors BF_i and BF_{i+1}. The FPR method was then applied to determine the relative weight (WB_i) of the ten key factors that affect the bid / no bid decision.

Assessing the risk score for factors of influence on bid / no bid decision making

Risk score RS_i represents the degree of risk in the factor of influence BF_i. The PDMs employed predetermined scores {0-No risk, 25-Low risk, 50-Moderate risk, 75-High risk, 100-Prohibitive risk} to assess each factor subjectively.

Deciding to or not to submit a bid

The bid / no bid score V_B may then be calculated by summing $WB_i \times RS_i$ for the ten key factors. If $V_B \le 50$, then a "bid" decision is recommended. Bid / no bid score totals for cases 1 through 3 returned, respectively, 43.8, 52.9 and 45.3. Therefore, the contractor should bid on Case 1 and Case 3, and proceed to Phase III.

Phase III - Assigning an Appropriate Markup

After a positive decision to bid is made in Phase II, this phase assesses the optimal markup scale to use on the project to be bid based on PDM preferences. The probability of winning a project at a specific markup scale must first determine PDM utility and probability weighting functions in order to calculate recent successful markups, which may then be used to determine the optimal PDM markup. The process of determining such is presented below.

Assign markup scale

In construction projects, the scale of a markup is determined based on relevant contractor policies and project type. This study employed five frequently used markup scales, including {$M_1 = 3\%$, $M_2 = 4\%$, $M_3 = 5\%$, $M_4 = 7\%$, $M_5 = 10\%$}.

Determine relative weight of influential factors on special markup scale

The eight key factors previously identified as affecting markup scale decision making (MF_i) are listed in Table 2. Assigning weights to each factor WM_i is done in the same manner as determining the relative weight of influential factors in bid / no bid decisions.

Forecast the probability of winning a project using a specific markup scale

As bids typically involve multiple potential contractors, assessing the probability of bid success over competitors at a particular markup level is critical. Of course, the markup scale can be expected to correlate inversely with probability of bid success. FPR was used here to forecast win probability ratings for relevant factors of influence factors MF_i. Finally, for a specify markup scale, the forecast probability of winning PM may be obtained by summing $WM_i \times PR_i$.

Elicit the PDM Utility Function for the Markup Scale

This study adopted the TO method proposed by Wakker et al. (1996) to elicit the PDM utility function for the markup scale. This paper will not describe the mechanisms by which such was accomplished, as the method has been described previously in the literature (Bleichrodt et al., 2000; Abdellaoui, 2000; Abdellaoui et al., 2005). The elicited result for the PDM utility function is shown in Figure 2.

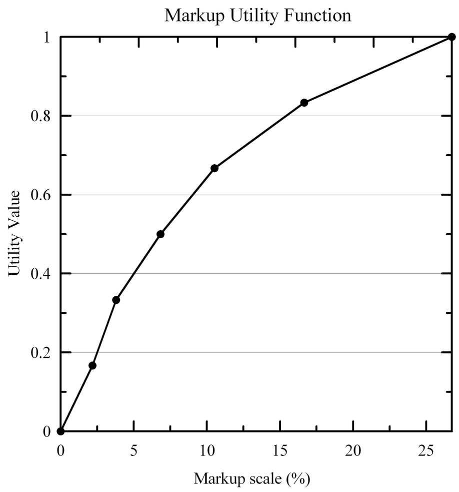

Figure 2: Elicited PDM Utility Function of the Markup Scale

Elicit the PDM Probability Weighting Function

Bleichrodt et al. (2000) proposed a method to elicit PWF based on the TO method. This study used the same probabilities p'={0.10, 0.25, 0.50, 0.75, 0.90} as those in Bleichrodt's study to elicit a PWF for the PDMs. In the elicitation procedure, the PDMs may be used to assess an outcome for the two prospects in probabilities that ranged between 0.10 and 0.90. Figure 3 shows the elicited PWF of the PDMs in this study.

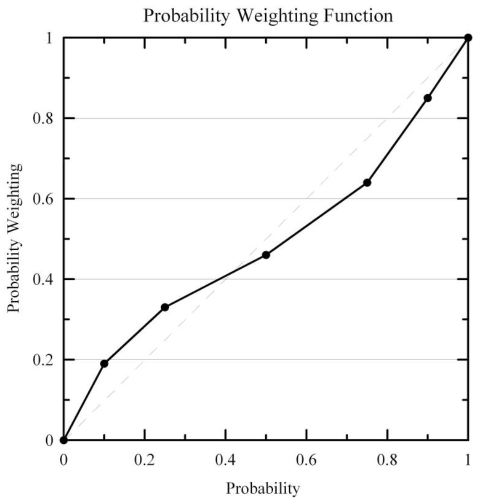

Figure 3: Elicited PDM Probability Weighting Function

Determine the Markup Scale Prospect Value

Under CPT and FPR, the Prospect Value $V_{CPT}\left(M_i\right)$ at a specified markup scale M_i may be determined using the CPT equation $V_{CPT}(M_i) = U(M_i) \times W(PM_i)$, where $U\left(M_i\right)$ and $W\left(PM_i\right)$ may be interpolated from the PDM Utility Function and Probability Weighting Function. The calculated CPT values for each markup scale in Case 1 and Case 3 are listed in Table 4.

Table 4: CPT value for each markup scale in cases 1 and 3

Case	Markup scale M(n)	Markup scale Utility Value U(M(n))	Probability of Winning P(M(n))	Probability Weight PW(M(n))	Prospect Value V_{CPT}	Decision Markup scale
1	3%	0.252	78%	0.682	0.172	5%
	4%	0.345	71%	0.611	0.211	
	5%	0.400	63%	0.554	0.221	
	7%	0.508	43%	0.424	0.215	
	10%	0.643	25%	0.330	0.212	
3	3%	0.252	77%	0.668	0.168	7%
	4%	0.345	68%	0.590	0.203	
	5%	0.400	60%	0.532	0.213	
	7%	0.508	46%	0.439	0.223	
	10%	0.643	28%	0.345	0.222	

Comparison and Decision Making

Selecting the highest markup scale CPT value (Table 4) determined the markup scale in each case (i.e., 5% for Case 1 and 7% for Case 3). Estimated profit and bid price for Cases 1 and 3 were calculated and are shown in Table 5. Under circumstances in which contractors may only choose one case on which to bid, other consideration factors may be brought into play (e.g., duration, funding requirements, etc.).

Table 5: Profit and bid price for cases 1 and 3

Case	Estimated Cost (USD)	Decision Markup scale	Profit (USD)	Bid price (USD)
1	17,954,000	5%	897,700	18,851,700
3	9,735,000	7%	681,450	10,416,450

CONCLUSIONS

A Multi-Criteria Prospect Model for Bidding Decision (BD-MCPM) was developed to help contractors determine whether to submit a bid and to set an effective markup scale. Research contributions include:

1. The most important factors contractors in Vietnam consider when making bid / no bid and markup decisions were identified through a review of relevant literature. Forty-four and 29 potential factors for bid / no bid and markup decision making, respectively, were identified and then filtered using the questionnaire analysis method to a shortlist of ten and eight, respectively.

2. A BD-MCPM systematic bidding model was developed using the Multi-Criteria Prospect Model (MCPM) with prescriptive variables based on the 18 abovementioned factors. This model may be implemented by contractors in real situations to achieve practical results, unlike the results achieved by most previous research work.

3. The developed BD-MCPM model was validated on actual project bids obtained from surveys of construction companies operating in Vietnam and helped PDMs successfully select cases on which to bid and set optimal markups.

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