Contractor's Opportunistic Bidding Behavior and Equilibrium Price Level in the Construction Market

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Abstract: The competitive bidding system has been to blame for abnormally low bids, which are considered as one of the main causes of poor project quality. Previous studies have regarded the pricing of bidders as an optimum decision based on contractor's cost and market competition level. However, the sell to produce characteristic of construction projects may induce contractors to offer a low bid and then make up the amount initially sacrificed from beyond-contractual reward (BCR) gained through cutting corners and claims. System dynamics was adopted in this study to develop a contractor's pricing model with consideration of the dimensions of cost, market competition, and BCR. The model was then examined by statistical analysis of data collected from 44 highway projects in Taiwan. It was found that the equilibrium market price is significantly associated with BCR, which is assumed to be determined by the strictness of the owner's construction management, including both soundness of contract and tightness in construction supervision. Research results suggest that contractors divide the market into different segments according to the owner's strictness of construction management and the equilibrium price level of each market segment varies. The price level for projects with a strict owner is remarkably higher than for those with relatively less strict owners. Improvement in the construction management system of projects is crucial to lower the possibility that contractors gain BCR and do opportunistic bidding, and to further enhance project quality.

DOI: 10.1061/(ASCE)0733-9364(2007)133:6(409)

CE Database subject headings: Construction industry; Bids; Pricing; Simulation models.

Introduction

Under the current competitive bidding system, fierce competition has long made contractors tender bidding prices substantially lower than owner's budgets. Such abnormally low bids have been widely regarded as the main cause of poor quality in public projects. Abnormally low bids were defined as any bid whose price appears abnormally low and consequently may cause implementation problems (Henriod and Lanteran 1988). In order to eliminate abnormally low bids, the Government of Taiwan has adopted a number of policies, e.g., average bid (Ioannou and Leu 1993), ceiling price method (Wang 2004), and the most advantageous tendering approach (Yang and Wang 2003). However, in the past few years, it has still been common that the award price for a public construction project is substantially lower than the budget. In some extreme cases, the awarded price was even 50% lower than the budget. According to research conducted by the Taiwan Construction Research Institute on construction companies in Taiwan, improper bidding systems and malignant competition have become the major causes that affect the development of the construction industry (Taiwan Construction Research Institute 2000).

Previous studies have regarded the pricing of bidders as an optimum decision on account of cost and/or market competition level (Friedman 1956; Carr 1982; Drew et al. 2001). Given constant cost factor, abnormally low bids are attributed to insufficient market demand, excessive number of competitors, and unsound bid awarding methods. However, due to the time lag caused by the sell to produce characteristic of construction projects, contractors may be able to obtain rewards by cutting corners or by claims. Some contractors may even take advantage of project conditions and adopt opportunistic bidding strategies, submitting an abnormally low bid and then profiting from cutting corners or raising claims. The purpose of this study is to analyze in depth contractors' opportunistic bidding behavior, and its impacts on the market price level.

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Note. Discussion open until November 1, 2007. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on December 6, 2005; approved on December 28, 2006. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 133, No. 6, June 1, 2007. ©ASCE, ISSN 0733-9364/2007/6-409–416/$25.00.

Beyond-Contractual Reward and Contractor's Opportunistic Bidding Behavior

In the competitive bidding system, price is the decisive criterion, so contractors may win the bid by tendering an abnormally low bid, accidentally or deliberately (Grogan 1992). When contractors begin construction under an unfavorable condition in terms of price, they often adopt some strategies to compensate for the deficit, such as (1) cutting corners to lower the cost (Winch 2000) or (2) bringing up claims against the owner (Crowley and Hancher 1995a). In this study, all compensations gained beyond the con-

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tract are called beyond-contractual reward (BCR).

In general, contractors tender an abnormally low bid due to insufficient professionalism or cursory calculation. Such situations are called "Winner's Curse" (Capen et al. 1971), by which the contractor who wins the bid undertakes the construction at a sacrifice. Winner's curse can be avoided by improving contractors' professionalism. The main factor that might cause serious problems for the construction market is contractors' deliberate low-bidding behavior. Doyle and DeStephanis (1990) warned that certain bidders extensively review the bid documents, noting mistakes, cataloging ambiguities, and looking for future change orders or claims. These bidders can lower their bid prices with the knowledge that on subsequent change orders or claims they can recapture monies that were initially sacrificed for the award (Crowley and Hancher 1995b). Rooke et al. (2004) introduced the concept of proactive claims and reactive claims and concluded that claims have been an important source of contractor's profit. Ho and Liu (2004) applied game theory to analyze the relationship between claims and contractors' bidding behavior and concluded that contractors will lower the bid when they expect profits from claims.

In this research, contractors' opportunistic bidding behavior refers to contractors' deliberate low bids that cannot accord with the cost and their intention to obtain BCR through cutting corners or claims after undertaking the construction.

Research Design

This study consists of two parts. In the first part, system dynamics was adopted to develop a contractor's pricing model with three dimensions of cost, market competition, and BCR. Iterative computer simulations are performed to analyze the effects of different pricing behaviors on market price level—with and without the consideration of BCR. In the second part, data collected from 44 highway projects in Taiwan, as well as a questionnaire survey, are used to verify the simulation results obtained in the first part.

Role of the System Dynamics Model

System dynamics (SD) is a modeling methodology whose purpose is to assist in the understanding of complex problems and provide an approach for representing the dynamic relationships between variables in a system. With a foundation of decision making, dynamic relationships, feedback analysis, and simulation, systems can be defined and modeled that will allow experimentation in a laboratory setting (Chasey et al. 2002). In the past decades, SD has been comprehensively used to analyze many complex social systems, particularly in industrial contexts (Rodrigues and Bowers 1996).

As contractors' pricing behaviors as well as the market price level are simultaneously influenced by many complex and interdependent factors, the SD model is not used to calculate contractors' bidding prices and exact market prices; instead, it is adopted to simulate how specific pricing behaviors affect the market price level by controlling variables such as contractor's cost, market competition level, and BCR. Through iterative simulations, the cause-effect relationships between specific variables of research interests can be understood from a systemic viewpoint.

Model Assumptions

From the supply perspective, a market defined by economic theory is attributed to a set of companies who produce homogenous products. In the construction industry, a market segment can be formed when there is a set of contractors who tend to compete for projects with similar production conditions, such as owner, project location, project type, scale, and so on. While many factors could affect a contractor's pricing, this research merely focuses on the three dimensions of cost, market competition, and BCR and makes the following assumptions:

1. Contractor's cost is defined as constant opportunity cost: The opportunity cost is defined as the lost benefit that the best alternative course of action could provide (Maher 1997). Therefore, if the contract price equals opportunity cost, it actually includes both the production expenditure and normal profit (Varian 1992). In addition, a contractor's pricing factors including bids in hand and work in hand (Drew and Skitmore 1992) are contained in this research with the use of the opportunity cost concept. Further, as contractor's cost is only used in this model to reflect contractors' bottom lines in pricing and market competition becomes the main consideration in pricing, contractors' costs are simplified as constant values.
2. The award prices of previous projects are assumed to be important references indicating competitor's price: Assume contractors aim to obtain maximum profit, and the goal of pricing is to look for a price which is minimally lower than that of any other competitors. To achieve this goal, bidders need to assess and predict prices that their competitors may offer before they determine their own price. This phenomenon has been described in the Bertrand competition model of economics (Carlton and Perloff 2000). In this case, the award prices of previous projects are assumed as important references to a competitor's price.
3. The level of competition is measured by the number of competitors and contractor's pricing will reflect changes in the number of competitors: Carr (1983) proposed that, as the number of competitors varies from project to project, contractors typically adjust their markups to reflect increases and decreases in competition. In addition, De et al. (1996) has proposed that the larger the number of competitors is, the lower the profit the winner gains. Accordingly, this study assumes that contractors adjust their bidding price based on the number of competitors.
4. There is potential BCR in all projects and the amount of BCR is affected by the strictness of the owner's construction management system, including soundness of contract and tightness of construction supervision: If an owner exercises a stricter construction management, there will be less BCR and a less strict construction management more BCR.

Measure of Market Price Level

As the construction projects are different in project size and work contents, this study applies the concept of price level to rescale the projects for comparison. "Bid/budget ratio" is used for the measurement of the market price level, as shown in

$$\text{bid/budget ratio} = \text{award price/budget} \tag{1}$$

Contractors' Pricing Model

To better explain contractors' pricing, this part will introduce contractors' pricing without and with the consideration of BCR, re-

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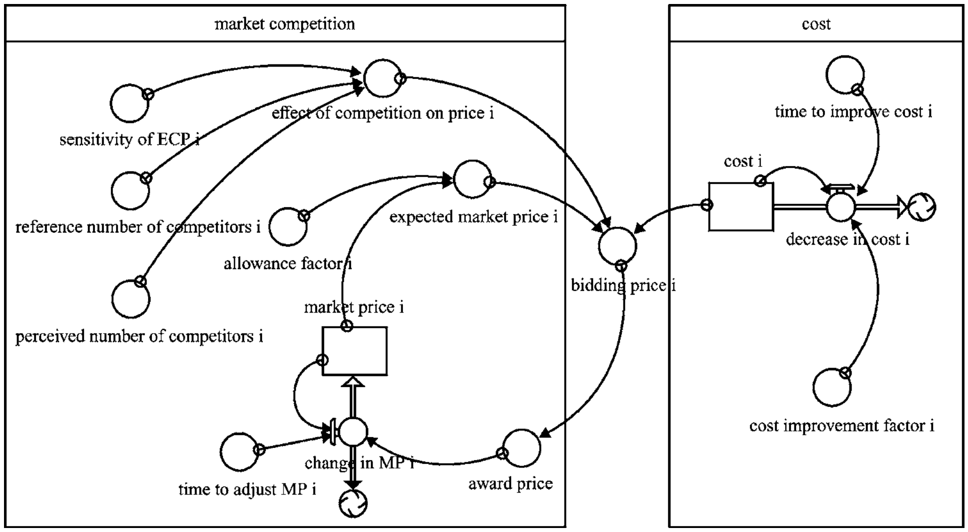

Fig. 1. Contractor's pricing without consideration of BCR

spectively, and then the market price level due to each pricing will be individually simulated and analyzed as well.

Pricing without the Consideration of BCR

This section explores contractors' pricing by assuming the BCR is not taken into account. As shown in Fig. 1, contractors' bidding price (BP) is influenced by interdependent variables from two dimensions of cost and market competition. According to the aforementioned assumptions, historical award prices [termed market price (MP), in Fig. 1] and number of competitors are the two fundamental considerations in the dimension of market competition. The relationships between each variable and contractors' bidding price are modeled as follows.

Modeling the Effect of MP on Contractors' Pricing

As MP is considered as a reference to competitors' prices, it is reasonable to assume that contractors will determine a price lower than MP, so as to win the bid. The adjusted price is called expected market price (EMP). The easiest adjustment can be made by making a discount on MP.

Assume that the number of competitors in the market is "n", the MP perceived by each competitor "i" differs with different timing and range of adjustment. Therefore, in Fig. 1, MP for each competitor is represented by "market price i", where i ranges from 1 to n. The same concept applies to other variables labeled with "i".

As MP=variable that varies with time and depends on the contractor's previous experience, this paper applies the typical stock-flow formulating technique in SD to propose the MP function by an integral equation as follows:

$$\text{MPi}(t) = \int_{t_0}^{t} [\text{change in MP i}] + \text{MPi}(t_0) \tag{2}$$

$$\text{change in MP i} = (\text{award price} - \text{MP i})/\text{time to adjust MP i} \tag{3}$$

$$\text{award price} = \text{MIN}(\text{bidding price i}) \tag{4}$$

where $MP(t_0)$ indicates the initial value of MP, change in MP indicates the net rate of change of MP. The change in MP function is a first-order linear negative feedback system, which allows for the corrective action to be a constant fraction per time period of the discrepancy between the desired and actual state of the system (Sterman 2000). Following the change in MP function, the MP can be constantly updated based on the discrepancy between previous MP and award price, so as to maintain MP as a representative reference. Time to adjust MP represents how quickly the contractor tries to correct the shortfall between MP and actual award price: if the contractor seeks to correct the shortfall quickly, the adjustment time would be small. Award price is the lowest price among all the offers.

With MP taken into account, the EMP can be expressed as in

$$\text{EMP i} = \text{MP i} \times \text{allowance factor i} \tag{5}$$

where allowance factor represents the discount rate on the market price. A higher discount rate indicates the contractor is more eager to win the bid.

Modeling the Effect of Number of Competitors on Contractors' Pricing

This study applies a variable, effect of competition on price (ECP), to indicate the effect of number of competitors on contractors' bidding price, as shown in the following equation. The bidding price is adjusted with regard to the number of competitors by MP × ECP

$$\text{ECP i} = \text{SECP i} \times [(\text{RNC i}/\text{PNC i}) - 1] \tag{6}$$

where reference number of competitors (RNC) is the predicted number of competitors based on previous bids (e.g., the average number of competitors in previous projects); and perceived number of competitors (PNC) is the number of competitors speculated before the bid. And sensitivity of ECP (SECP) represents the weight of this decision logic, where the value of SECP ranges from 0 to 1.

According to Eq. (6), the decision logic is as follows: If the PNC equals the RNC, after deciding the bidding price based on the MP, contractors do not need to make further adjustment in accordance with number of competitors; In this case, ECP equals 0. If PNC is larger than RNC, the competition is keener and ECP will be negative. Therefore, contractors will lower their price to

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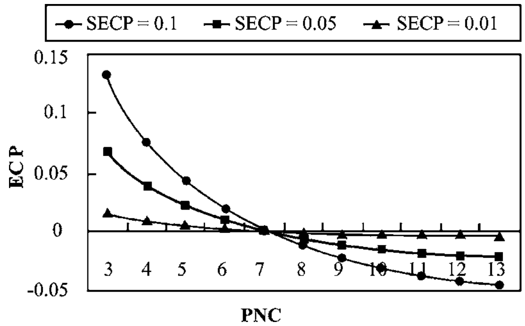

Fig. 2. The relationships between PNC and ECP

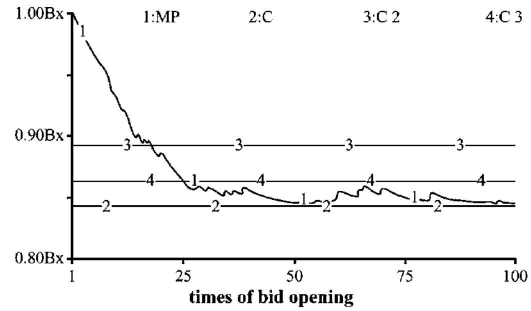

Fig. 3. Simulated market price trends neglecting BCR

win the bid. On the contrary, if the PNC is smaller than RNC, the bid is less competitive and ECP will be positive. In this case, contractors may raise their bidding prices.

The ranges of ECP are affected by SECP. The higher the SECP is, the more weight the contractor gives to the number of competitors in pricing, and the larger the range of adjustment. If a contractor's SECP equals 0, that means the contractor takes no consideration for the number of competitors at all. According to the 44 sample projects collected in this research, the number of competitors ranges from 3 to 13, and the average is 7. Therefore, in the model, the RNC is set as 7 and the PNC is set between 3 and 13. Fig. 2 shows the relationships between ECP and PNC with different settings of SECP.

To summarize, the decision function for contractors' bidding price with considerations of both MP and number of competitors is as follows:

$$\text{BP i} = (\text{EMP i} + \text{MP i} \times \text{ECP i}) \tag{7}$$

It is assumed that contractors will not perform the construction at a sacrifice, if the estimated price is lower than cost, they will not lower the price but stay at the cost. Therefore, a more comprehensive decision function for pricing of each individual contractor has been shown in the following equation where the contractors choose a maximum value among the estimated price and cost:

$$\text{BP i} = \text{MAX}[(\text{EMP i} + \text{MP i} \times \text{ECP i}),\ \text{Ci}] \tag{8}$$

where C indicates contractor's cost, MAX indicates contractors will choose a max value considering (EMP+MP×ECP) and C.

Simulation of Market Price Level

In this section, a simulation is conducted to portray the trend of market price when contractors proceed to determine their bidding price with the aforementioned pricing logics. The computer program used in this research is ithink Analyst 6.0.1 (i.think.Inc., Dallas, Tex.). The setting of each parameter in the model is shown in Table 1.

Table 1. Setting of Model Variables

Variable	Unit	Setting
Time to adjust MP	Times of bid opening	6–10
Allowance factor	NA	0.95–0.99
RNC	Company	7
PNC	Company	RANDOM(3, 13)
SECP	NA	0.05–0.10

The market price trend obtained by computer simulation is shown in Fig. 3. The X-axis indicates times of bid opening. Bx represents the initial budget estimated by the owner. The MP curve represents the simulated market price level that varies with time. C curve represents the cost of the contractor with the best cost advantage. C 2 and C 3 curves represent other contractor's costs. Note that the costs, C, C 2, and C 3 are presented in Fig. 3 for demonstrating different contractor's costs, whereas there are more contractors with other cost conditions in the market.

The simulation results reveal that, under the price competition mechanism, the initial market price, i.e., the budget estimated by the owner, reduces as time proceeds, until it gets very close to contractor's cost. In the short term, the market price level fluctuates as the number of competitors varies at different points of time. In the long term, the market price level will become stable and can be considered as an equilibrium market price level based on the assumed competition level and contractor's cost.

Throughout the process of competition, the market price lowers with the price offered by the contractor with the lowest cost. If a certain contractor does not efficiently reduce its cost (as shown in the C 2 and C 3 curves in Fig. 3), in the long run, this contractor will surely lose its competitiveness.

This section shows how contractors' pricing with considerations of cost and market competition factors will reach an equilibrium market price level after a period of competition. In this case, this equilibrium price will cover both contractor's production expenditure and normal profits. For the government, there will be no concern about excessive remuneration. This is the ideal "economy" situation advocated by the free market competition paradigm. Besides, such an ideal mechanism would also lead contractors to innovate in the use of production technologies to reduce costs, encouraging the growth of the contractors.

Pricing with the Consideration of BCR

This section explicates the contractors' pricing with the consideration of BCR. The pricing model is expanded as shown in Fig. 4.

This study developed a variable, reference beyond-contractual reward (RBCR), to represent contractors' perception of the possible amount of BCR which can be obtained from a project. It is assumed that contractors will use RBCR as maneuvering room to lower their bidding price when the market price level drops. Therefore, the decision function of contractors' pricing transforms from the equation of MAX[(EMP i+MP i×ECP i),Ci] into that of

$$\text{BP i} = \text{MAX}[(\text{EMP i} + \text{MP i} \times \text{ECP i}),\ \text{Ci} - \text{RBCR i}] \tag{9}$$

RBCR=variable that can constantly change in accord with previous experiences. The RBCR is directly influenced by previ-

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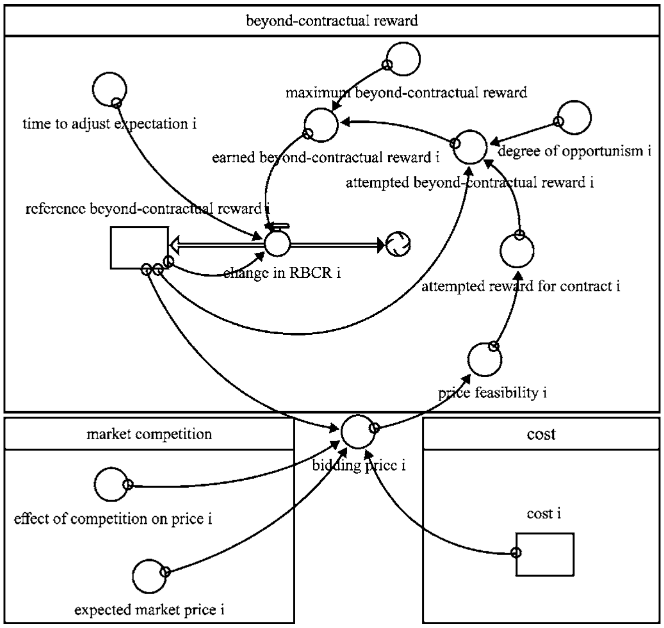

Fig. 4. Contractors' pricing with consideration of BCR

ous BCR; and contractors make adjustments of the discrepancy between the RBCR and BCR actually earned after each project. Therefore, this paper similarly applies the typical stock-flow and first-order linear negative feedback system formulating techniques in SD to construct the RBCR functions shown in

$$\text{RBCR i}(t) = \int_{t_0}^{t} [\text{change in RBCR i}] + \text{RBCR i}(t_0) \qquad (10)$$

$$\text{change in RBCR i} = (\text{EBCR i} - \text{RBCR i})/\text{time to adjust expectation i} \qquad (11)$$

where RBCR(t_0) indicates the initial value of RBCR; change in RBCR=net rate of change of RBCR; EBCR represents the earned beyond-contractual reward in the latest project; and time to adjust expectation=time needed for contractors to adjust their RBCR.

The EBCR is related to the strictness of the owner's construction management and how much BCR the contractor attempts to obtain. As the owner's construction management functions in reducing corner cutting and claims, it is reasonable to assume that there is a limit to BCR which can be obtained under a specific construction management system. Under different strictnesses of construction management on projects, even when all contractors intend to gain BCR, there should be differences among BCRs actually obtained. Accordingly, the EBCR is expressed as

$$\text{EBCR i} = \text{MIN}(\text{ABCR i, MBCR}) \qquad (12)$$

where ABCR=attempted beyond-contractual reward; MBCR =maximum beyond-contractual reward; and MIN indicates the minimum value between ABCR and MBCR.

There are two sources of ABCR; the first is the attempted BCR estimated by contractors to make up for sacrifices at the tender stage, termed attempted reward for contract (ARC). And the second is the contractor's opportunism. Further explanation is as follows:

1. Criterion for contractors' conducting abnormal behavior for ARC is price feasibility (PF), which is defined as: PF=BP/C. If BP/C<1, it means that the contractor will face loss and will be forced to pursue BCR. The lower the value of BP/C is, the higher the ARC of contractors. If BP/C>1, it means that the bidding price covers part of the contractor's profit, so the contractor has no pressure to look for ARC.
2. Opportunism is one of the most important behavioral assumptions in economic theories. It says that companies always want more of what they like, and this may imply that interests are pursued in an opportunistic fashion (Williamson 1985). Thus, it is reasonable to assume that, when the contractors have experienced obtaining BCRs in the past, they tend to repeat the abnormal behavior in order to gain the maximum profit, whether the award price is reasonable or not. Further, as contractors do not know how much BCR is the limit, they will try to attempt more BCR than RBCR to maximize their rewards.

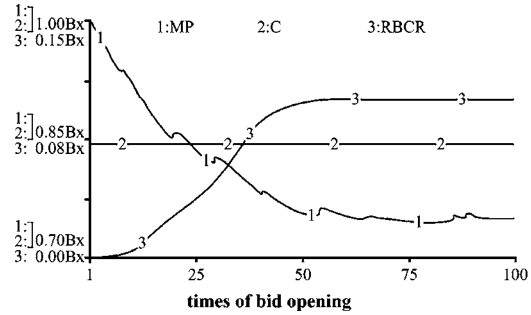

Fig. 5. Simulated market price trends after contractors consider BCR in pricing

Based on the aforementioned assumptions, ABCR is expressed in the following equation as the maximum value between ARC and (RBCR+RBCR×DO):

$$\text{ABCR i} = \text{MAX}[\text{ARC i}, (\text{RBCR i} + \text{RBCR i} \times \text{DO i})] \qquad (13)$$

where DO represents contractors' degree of opportunism. DO ranges between 0 and 1 in this study, and the higher it is, the stronger the tendency for the contractor to indulge in abnormal behaviors for RBCR.

Simulation of Market Price Level

Following the same setting of parameters for simulations aforementioned, it is further assumed that the maximum BCR is 10% of owner's budget (MBCR=0.1Bx). Then, even though the market price trends in the computer simulation still feature effects of market competition, obviously, the market price has become lower than the contractors' cost (Fig. 5). Contractors' expectation of BCR is a feedback process in which the RBCR is evolved from contractors' previous experiences. After a period of time and experience accumulated, the RBCR in the projects supervised by specific project owners will become more assessable and converge toward the limit. The level of RBCR reflects the gaps between market price level and contractor's cost in Fig. 5 (see Table 2 for numerical results).

Further, market prices produced under different market competition levels are examined. As seen in the aforementioned case, the reference number of competitors assumed by contractors is 7; when the number exceeds 7, price competition among contractors becomes keener. Therefore, the parameter, PNC, was set as RAN-

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Table 2. Numerical Analysis of the Simulation Results with the Consideration of BCR

Times of bid opening	MP (unit: Bx)	C (unit: Bx)	RBCR (unit: Bx)
Initial	1.000	0.842	0.000
10	0.929	0.842	0.008
20	0.858	0.842	0.022
30	0.821	0.842	0.044
40	0.788	0.842	0.080
50	0.765	0.842	0.097
60	0.747	0.842	0.099
70	0.751	0.842	0.099
80	0.757	0.842	0.099
90	0.744	0.842	0.099
100	0.748	0.842	0.100

DOM (8–13), RANDOM (5–10), and RANDOM (3–6) to simulate the market price trends under three distinctive market competition levels, very keen, moderate, and very slack.

The computer simulation showed that the market prices reached under different competition levels still can drop to a price level lower than contractor's cost (see Fig. 6 where the curve MP stands for moderate level of competition, MP2 stands for very keen competition level, and MP3 stands for very slack competition level). Further, when the market reaches a certain competition level, it forces contractors to lower their bidding prices and depend upon BCR (in cases of PNC at least more than 5 in this study), even under different competition levels, the effects of competition level will be minor and all market prices eventually gather at the same equilibrium price, the contractors' cost minus BCR (refer to the curves MP and MP2 in Fig. 6).

Summary

In cases without regard for BCR, the competitive bidding system assumes that the bidding prices of all contractors reflect their cost, and they abide by the contract and requirements for quality. However, results of the simulations reveal that, when excessive room for BCR exists in the market, contractors who apply opportunistic bidding behavior enjoy a higher possibility to take extra market share. Moreover, after contractors obtain BCRs, consequently their expectation for BCR in future construction projects rises. This will induce them to tender even lower prices, and then pursue compensation from BCR. Hence, even when the market price is moving toward a certain equilibrium level with time, the market price turns out to be lower than contractors' cost, forcing other contractors in the market to survive upon BCR.

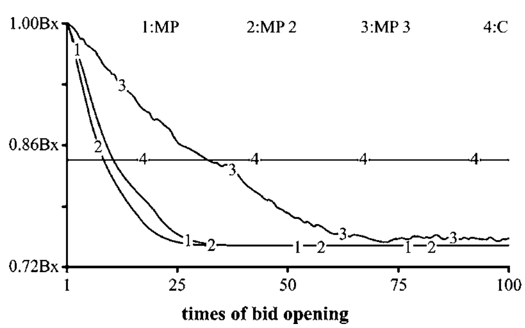

Fig. 6. Simulated market price trends under various competition levels

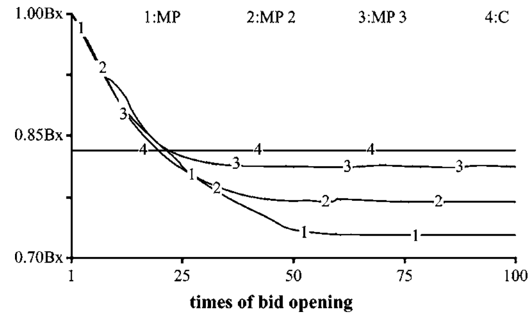

Fig. 7. Simulated market price trends under different BCR conditions

Effects of BCR on the Market Price Level

In this section, the influence of BCR on the equilibrium market price level is examined. Since the degree of strictness of the owner's construction management on the project is assumed to affect the maximum amount of BCR, MBCR can be used to represent different strictnesses of construction management in different projects. The lower MBCR is, the stricter the construction management; and vice versa.

The MBCR is separately set as 0.1Bx, $0.06B_x$, and $0.02B_x$ to simulate the market prices under three different degrees of strictness of owner's construction management on projects. The simulation result shows that, at the same competition level, different BCR levels result in different equilibriums of market price (see Fig. 7). It is logical to infer from this result that, when contractors begin to take BCR into account for pricing decisions, the key determinant of contractors' pricing and market price is BCR instead of market competition level. Therefore, projects with different degrees of strictness in construction management would be naturally divided into different market segments, and their equilibrium market prices vary as well.

Case Study

In this study, 44 highway projects that include similar road and bridge construction are considered homogenous and selected from two government agencies in Taiwan, the National Expressway Engineering Bureau (NEEB) and the Directorate General of Highways (DGH). Data collected from the above sample projects are analyzed to verify the relationship between the strictness of construction management and the award price level (please refer to Table 3, for the sample projects).

Table 3. Background of Sample Projects

	Owner	
Background of samples	NEEB	DGH
Number of samples	26	18
Budget ranges	9–53 billion TWD	3–55 billion TWD
Award price ranges	7–35 billion TWD	1.5–26 billion TWD
Date of bid opening	1998–2001	1995–2003
Average number of competitors	6.5	7

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Table 4. Analysis of Strictness of Construction Management by NEEB and DGH

Evaluation aspects		Average NEEB	Average DGH	t-test (p value)
Soundness of contract provisions	For material	6.50	5.42	0.001
	For construction	6.42	5.08	0.001
Tightness of construction supervision	For material	6.67	5.25	0.000
	For construction	6.58	5.08	0.000

Strictness of Construction Management

To distinguish the strictness of construction management on projects by NEEB and DGH, 12 of 19 contractors who have participated in projects for both NEEB and DGH were interviewed (four contractors have closed down and three contractors did not agreed to be interviewed). Every contractor interviewed graded NEEB and DGH based on previous experience from two aspects: soundness of contract provisions and tightness of construction supervision. The scores ranged from 1 to 7; 1 means very loose and 7 means very strict. Results from the survey reveal that NEEB scores significantly higher than DGH in terms of the soundness of contract provisions and tightness of construction supervision (see Table 4).

Award Price Level

It was found that the price levels of sample projects are correlated to the date of bid opening and number of competitors (the Pearson correlation coefficients are 0.47 and 0.68, respectively). Therefore, to exclude the influences of these two factors on the price level and precisely compare the price level of two agencies, this paper applies multivariate regression to assess each variable's impact on price level, as shown in

$$P = \beta_1 T + \beta_2 N + \beta_3 G_a + \beta_4 G_b \tag{14}$$

where P represents award price level; T=date of bid opening; N=number of competitors; G_a=NEEB; and G_b=DGH. As G_a and G_b represent two categories, each is marked as a dummy variable: 0 or 1 (Hardy 1993).

Statistics shows that, excluding the effects of bid-opening date and number of competitors on award price level, the β_3 and β_4 estimated are 0.624 and 0.585, respectively, this suggests that under similar market conditions, price levels for projects operated by NEEB will be higher than for those operated by DGH (see Table 5).

Reliability is supported by the result that each variable has a significant influence on the price level of the sample projects (t-value of each variable is less than 0.05) and all the variables are independent of each other (condition index value of each variable is less than 30). Therefore, this analysis substantially supports the idea that, when contractors participate in DGH projects, they expect higher BCR and tender lower prices; so the award price level is significantly lower than in the case of NEEB.

Table 5. Parameter Estimation Figured by Multivariate Regression

Variables evaluated	β	t-test (p value)	Condition index	R^2
Date of bid opening	0.034	0.000	4.097	
Number of competitors	–0.014	0.007	8.163	0.989
NEEB	0.624	0.000	1.000	
DGH	0.585	0.000	1.659	

Conclusions

Contractors' pricing behaviors as well as the market price level are simultaneously influenced by many complex and interdependent factors. It is thus worthwhile to develop a holistic model which is capable of conducting scenario simulation in a laboratory setting, so as to increase our understanding of the dynamics of contractors' pricing behaviors and the market price level. This work broadly adopted findings of previous studies and carefully simplified and assumed some variables and parameters to build a model for analyzing contractors' opportunistic bidding behavior and its impacts on the market price level. It is found that the BCR is a crucial factor in the segmentation of the competition market by contractors. Results from both computer simulation and case study reveal a significant relationship between the market price level and BCR. It is inferred that, even under similar production conditions, construction projects let by owners of different degrees of strictness in construction management, from contractors' point of view, are to be categorized into different market segments. In a fiercely competitive market, the phenomenon that contractors decide the price on the basis of BCR and perform opportunistic bidding can very possibly be regarded as a modern market pattern. Therefore, this paper suggests that studies on the market price in the construction industry or related market economy issues cannot overlook the BCR and contractors' opportunistic bidding behavior in the construction market.

Contractors' opportunistic bidding behavior has long negatively affected quality of public projects. In the past, authorities concerned have invested immense efforts into the development of alternative bid awarding methods in an attempt to solve this problem. However, the research results have disclosed another problem area; the key motivation in contractors' opportunistic bidding is the potential BCR in the current construction management system. Therefore, improvement in the construction management system is crucial to lower the possibility that contractors gain BCR and engage in opportunistic bidding behaviors, and to further enhance project quality.

This study has limited its focus to the three major factors of cost, market competition, and BCR, while recognizing that factors such as technology transfer, market access, etc., can also affect the contractors' pricing decisions. Further, the assumptions of contractor's pricing behavior in response to changes of level of competition, previous award price, and contractor's expectation for BCR are certainly limitations in this research. As the proposed model was developed for simulation purpose, future studies are suggested to modify the variables and assumptions or to extend the model's boundaries from this pilot study, so as to address other important issues.

Notation

The following symbols are used in this paper:

ABCR = attempted beyond-contractual reward;
AP = award price;
ARC = attempted reward for contract;
BP = bidding price;

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C = cost;
DO = degree of opportunism;
EBCR = earned beyond-contractual reward;
ECP = effect of competition on price;
EMP = expected market price;
MBCR = maximum beyond-contractual reward;
MP = market price;
RBCR = reference beyond-contractual reward;
PF = price feasibility;
PNC = perceived number of competitors;
RNC = reference number of competitors; and
SECP = sensitivity of ECP.

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