Exploring Contractor's Opportunistic Bidding Behavior and its Impacts on Construction Market

Chien-Liang Lin
Department of Construction Engineering, National Kaohsiung First University of Science and Technology
Address: 2, Juoyue Rd., Nantz District, Kaohsiung 811, Taiwan.
TEL:886-7-6011000-2129
FAX:886-7-6011237
E-mail: ken@ccms.nkfust.edu.tw

Wei Lo
Department of Construction Engineering, National Kaohsiung First University of Science and Technology
Address: 2, Juoyue Rd., Nantz District, Kaohsiung 811, Taiwan.
TEL:886-7-6011000-2123
FAX:886-7-6011237
E-mail: roylo@ccms.nkfust.edu.tw

Min-Ren Yan
Institute of Engineering Science and Technology, National Kaohsiung First University of Science and Technology
Address: 2, Juoyue Rd., Nantz District, Kaohsiung 811, Taiwan.
TEL:886-7-6011000-2128
FAX:886-7-6011237
E-mail: u9015908@ccms.nkfust.edu.tw

Competitive bidding system, bearing the advantages of simplicity and fairness, is expected to encourage economic benefits through the free market competition mechanism. However, as the characteristics of construction industry are different from those of other industries, many issues such as abnormal low-bids and poor project quality have been derived from the competitive bidding system, and hinder the development of the construction market. By using System Dynamics this research developed a contractor's pricing model consisting of two intended economic feedback structures with competitive bidding philosophy and an unexpected adverse one, namely Opportunistic Bidding feedback structure.

The results suggest that the ideal competitive bidding system is only effective when contractor's opportunistic bidding behaviors are restrained. The emphasis of government's policies should be placed on inhibiting the Opportunistic Bidding, as it is the leverage point to improve the efficiency of public construction market.

Keywords: system dynamics, construction industry, competitive bidding, pricing, project quality, simulation

1. Introduction

Competitive bidding system plays a central role in the functioning of public agencies in many countries. Owners utilize competitive bidding system for its simplicity and fairness in the award process (Rankin et. al, 1996). In addition, it is expected that the system encourage efficiency and innovation by contractors, which hopefully results in a completed project of specified quality at the lowest possible price (Assaf et. al, 1998). This concept matches the free market competition mechanism advocated in the economics by Adam Smith. However, as the construction industry has certain characteristics unique to those of other industries, the benefits of competitive bidding system may not be fully utilized in the construction market. The construction project owners have to award some contractors then the construction process can begin. This "sell to produce" characteristic makes the quality of the final product is not sure in the tendering stage.

Under the competitive bidding system, because price is the sole selection criteria, contractors may win the bid by tendering an abnormally low bid, accidentally or deliberately (Grogan, 1992). When contractors begin the construction under an unfavorable condition in terms of price, they would adopt some strategies to compensate for the deficit, such as cutting corners to lower the cost (Winch, 2000) or bringing up claims against the owner (Crowley and Hancher, 1995a). In this research, the profits gained beyond the contract are called "beyond-contractual reward" (BCR). When a contractor attempts to obtain BCR, not only will the project quality be lowered but also the owner has to invest additional expenses on amendment. However, the worst of contractor's deliberate low-bidding doesn't end up with the failure of a single project, but the arising of opportunistic bidding habit which contractors resort to competing projects subsequently. Dolye and DeStephanis (1990) addressed that contractors can lower their bid price with the knowledge that on subsequent claims they can recapture monies that were initially sacrificed for the award. Ho and Liu (2004) applied Game Theory to analyze the relationship between claims and contractors' bidding behavior and concluded that contractors would lower the bid when they expect profits from claims. In this paper, it is manifested that the contractor sacrificed their bid price for not only subsequent claims but also compensations by cutting corners and claims. This circumstance leads to unreasonably low awarded-price in the market. Moreover, ignorance of project quality and the extra cost born to project owners will also be incurred. Consequently, contractors following the specified project quality standard and valuing cost renovation are unlikely to win the award. The subsequent malfunction of the free market competition mechanism is called "market failure" in this paper.

In Taiwan, as competitive bidding system has been mainly used in public projects for decades, many problems have been discovered, from bidding collusion in early times to abnormal low-bids in the present construction market. In order to eliminate abnormal low-bids, government of Taiwan has adopted a number of policies, e.g., average-bid method (Ioannou and Leu, 1993), ceiling price method (Wang, 2004), and best value contracting method (Yang and Wang, 2003). However, for the past few years, it was still common that the award price of the public projects is quite low; in some extreme cases, it was even 50% lower than the budget. According to the research conducted by Taiwan Construction Research Institute (TCRI), improper bidding system and malignant competition for bid was ranked the utmost cause that affects the development of construction industry in Taiwan (TCRI, 2000). Apparently, the problems of contractor's opportunistic bidding behavior have caused serious impacts on the whole construction industry in Taiwan.

2. Research Objective

Previous researches have been focusing on the flaws of the competitive bidding system, but there are insufficient systematic analyses regarding the correlation between competitive bidding system and contractors' pricing behavior as well as the causes of market failure, due to the complex interactions of involved variables. Since experiences reveal that the issues incurred by the competitive bidding system seem to be not unusual, there is a need to study the causes of market failure in the construction industry by a more comprehensive and systematic method.

This paper studies how contractor's opportunistic bidding behaviors are related to market failure, what situations will the behaviors be encouraged, and how to analyze its effect on construction industry. The objective of this research is to explore an underlying adverse feedback structure that is derived from contractor's opportunistic behaviors. By using System Dynamics (SD), this research developed a contractor's pricing model, which includes two intended economic feedback structures with competitive bidding philosophy and an unexpected adverse one. Through iterative computer simulations, the effects of each feedback structure can be evaluated so as to analyze the causes of market failures and corresponding managerial policies.

3. Model Testing: the Partial Model Tests Approach

The goal of model testing is not to "prove" a model is "right". Ayer (1952) addressed that the only statements can be validated are pure analytic statements; thus, it is unreasonable to verify a SD model which is developed to mimic social systems. Alternatively, model testing focuses on the iterative process to build confidence that a model is appropriate for the research purpose. A wide range of specific tests have been developed to uncover flaws and improve models in SD fields (Sterman, 2000). In this paper, the Partial Model Test was adopted as a main approach to challenge the applicability of the proposed model.

As the feedback structures are complicated and mostly composed of non-linear behaviors, it is almost impossible to verify the validity by solely mental model. Partial Model Tests are extensively applied in this research to assist resolving the aforementioned problem. In a partial model test, the interested function or variable is controlled in an exclusive environment independent to interactions or influences from the other variables or functions, to test its intended rationality when it was initially developed.

For instance, each loop in a three-feedback-loop system can be analyzed independently when the other two loops are temporarily excluded and deemed as exogenous to the system. After each component of a complicated system passes the verification of Partial Model Tests, the reliability of the model is further enhanced.

4. The Intended Economic Feedback Structures

This section explains how contractors' pricing decisions form the economic system under competitive bidding system.

Previous studies have shown that contractors determine the bidding price by means of "cost markup", i.e., contractors will decide an appropriate markup, or margin, to add to the estimated cost of the project to arrive at the contract price. The markup is usually expressed as a percentage of the total estimated cost (Fayek, 1998). In addition, it is the price that contractors compete with each other; therefore, the decision on markup is directly influenced by the degree of competition in the market. Thus, this research attributes contractors' pricing decision to two dimensions, "market competition" and "cost".

To better explain contractor's pricing, it is initially assumed that the difference of contractors' costs for a certain construction projects is minimal, and the pricing that involves only market competition factors will be firstly discussed later in this paper.

4.1 On Assumption that Cost Difference is Minimal

Given that all the contractors' estimated costs are very close, the impact of cost factors can be ignored. In this condition, the key to win the bid lies in contractors' markup setting, hence the price with a minimum markup will be the lowest 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, a bidder need to assess and predict prices that his competitors may offer before determining his own bidding price. In this case, the award prices of previous projects become an important reference, which was termed "*reference market price*" *(RMP)* in the model. In order to win the bid, contractors have to set their prices lower than the *RMP*.

In addition, 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"; which is termed "*level of competition*" in this paper.

Consequently, "*reference market price*" and "*level of competition*" becomes the critical information in the dimension of market competition.

The causal diagram of how contractors determine their bidding price with regard to *"reference market price"* and *"level of competition"* is developed and shown as figure 1. The price setting process forms a feedback structure, namely "Price Competition Feedback structure", upon which are elaborated as follows.

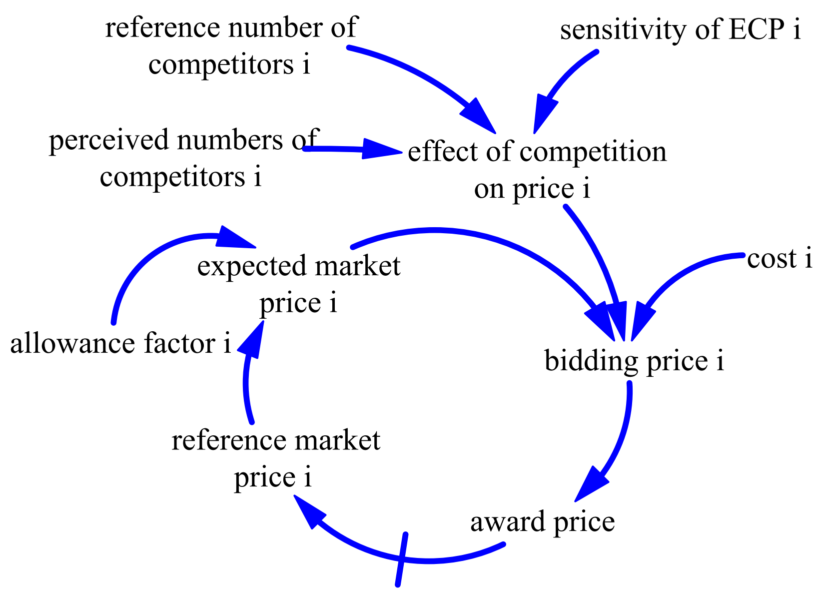

Figure 1. Price Competition Feedback structure

(1) Relationship Between *RMP* and Contractor's Bidding Price

To win the bid, contractors decide the bidding price after they predict possible prices of their competitors on the basis of *RMP*. Due to the continuous competitions, each contractor will improve its experience, technology, and management skill, hence cause the cost and bidding price to drop. Accordingly the *RMP* keeps dropping as time evolves and exhibit a pattern of exponential decay which was also termed "First-order Linear Negative Feedback" in SD (Sterman, 2000). Contractors constantly update and adjust their new *RMP* based on the discrepancy between previous *RMP* and award price. By doing so, the *RMP* will approach a reasonable lowest price among all competitors. Assume there are *n* competitors in the market, the *RMP* perceived by each competitor *i* may differ due to the possibly delayed and distorted market information in the real world. Therefore, in Figure 1, *RMP* of competitor *i* is represented by "*reference* *market price i"*, where *i* ranges from 1 to *n*. The same concept applies to other variables labeled with *i*. With *RMP* taken into account, the price adjusted down by a contractor is called *"expected market price i"(EMP_i)*. The adjustment can be made by multiplying an allowance factor on *RMP,* which is shown in Equation *(1)*:

$$EMP_i = RMP_i * allowance\ factor_i\ (\$) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where "*allowance factor"* represents the discount coefficient of market price. The lower the allowance factor, the greater the eager to win the bid.

(2) Relationship Between Level of Competition and Contractor's Bidding Price

De et al. (1996) has verified that the more the competitors, the lower the profit gained. Accordingly, contractors would adjust their expected profit based on the level of competition before they determine the bidding price. There have been numerous studies on bidding strategies, e.g., Friderman (1956), Gates (1976), Carr (1982), Drew et al. (2001); and they vary with respect to the criteria for measurement on competition level. This research applies "*number of competitors*" to represent competition level. The more bidders there are in for a project, the more competitive the project is.

A variable, "*effect of competition on price*" *(ECP)* represents the influence of competition level on the bidding price. *ECP* is determined by three variables, namely, *"reference number of competitors" (RNC)*, *"perceived number of competitors" (PNC)*, and *"sensitivity of ECP" (SECP)*, which are detailed as equation *(2)*:

$$ECP_i = SECP_i \times \left[\frac{RNC_i}{PNC_i} - 1 \right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

RNC is the predicted number of bidders based on previous bids (for example, the average number of bidders in previous projects); and *PNC* is the number of bidders perceived by a contractor before bidding. If the *PNC* equals the *RNC* preset by a contractor, after deciding the bidding price based on the *RMP*, the contractor does not need to make any adjustment on his bidding price; in this case, *ECP* equals 0. If the *PNC* is larger than *RNC*, the competition is keener and bidders will lower their price to win the bid; therefore *ECP* will be negative. On the contrary, if the *PNC* is smaller than *RNC*, the bid is less competitive, so they will tend to raise their bidding price; hence the *ECP* will be positive. Bidding prices are also assumed to respond to contractors' beliefs about the level of competition. The strength of the effect is determined by the *SECP*, where the value ranges from 0 to 1. The more sensitive the contractor feels about the competition, the more he will adjust the bidding price. If a contractor's *SECP* equals 0, that means the contractor takes no consideration for competition level of the project at all.

To summarize, the bidding price is adjusted with regard to the competition level by *ETC * ECP* and the decision function for the determination of bidding price is as equation *(3)*.

$$BP_i = (EMP_i + ETC_i * ECP_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where *BP* indicates contractor's bidding price, *ETC* indicates contractor's expected total cost.

Since 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 their variable costs. Therefore, a more comprehensive decision function for pricing of each individual contractor has been shown as equation *(4)* where the contractors choose a maximum value among the estimated price and cost:

$$BP_i = MAX\,[(EMP_i + ETC_i * ECP_i),\, EVC_i] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where *EVC* indicates contractor's expected variable cost, MAX indicates contractors will choose a max value between *(EMP + ETC * ECP)* and *EVC*.

Effect of Price Competition Feedback structure on the Market Price

In this section, trends of market price will be predicted by simulation in which contractor's bidding price is only influenced and governed by the "Price Competition Feedback structure".

Due to the uniqueness of construction projects, this research applies the concept of "price level" to re-scale and standardize the prices of various projects for comparison. "Bid/budget ratio" is used as an index of the market price level, as shown in equation *(5)*:

$$bid\,/\,budget\ ratio = \frac{award\ \ price}{budget} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

It is assumed that the budget in equation *(5)* is capable of reflecting the project cost. The budget estimated by the government usually conforms to the average market price. However, contractors' actual cost is usually lower than the government's estimate due to their experiences, economies of scale, and better control over the resource of specific materials. Since the final biding price of public projects can not exceed the budget, the value of bid/budget ratio ranges between 0 and 1.

The price trend simulated by computer is shown in Figure 2. The X-axis indicates time, and the unit is month. The Y-axis indicates market price, and the unit is dollar. The setting of each parameter in the model is shown in Table 1.

Table 1. The Setting of Model Variables

Variable	Unit	Setting
Time to adjust price trend	Month	6
Allowance factor	NA	0.95~0.99
Reference number of competitors	Company	7
Perceived numbers of competitors	Company	RANDOM(3, 13)
Sensitivity of effect	NA	0.09

It is revealed in Figure 2 that under the effect of "Price Competition Feedback structure", market price varies with time, and "RMP" curve indicates that when there is no fluctuation in market competition (the numbers of competitors are equal in every bid), bidders' price is driven only by the competition of the *"reference market price"*. In other words, as time proceeds, the market price decreases smoothly from the owner's budget to bidders' cost, the equilibrium price. "RMP 2" curve indicates that when *"reference market price"* and *"level of competition"* are simultaneously considered, the market price is also on the decrease, but with fluctuations in every section of time. The fluctuations are attributed to the random number of bidders for different projects in different time points.

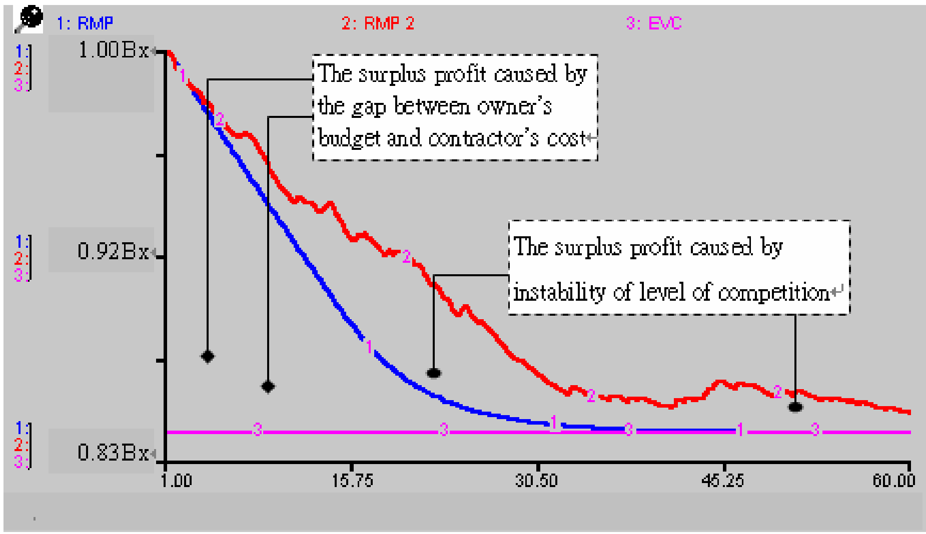

Figure 2. The Market Price under the effect of Price Competition Feedback structure

Figure 2 is helpful to explain the economic implications of the competitive bidding system. The market price can decrease from owner's budget to contractor's variable cost through price competition mechanism. The equilibrium market price is considered as a fair market price, which covers contractor's cost and removes surplus profit, and reaches an "economy" state. However, in practice, there are two potential kinds of surplus profit. First, because the government's budget is usually set too high, contractors can continuously and cumulatively make a surplus profit until the market price is very close to their cost limit, which is the area enclosed by "EVC" and "RMP" curves in Figure 2. Second, due to the variable competitions in every project, bidders' prices may not constantly drop because some bidders may temporarily raise their price in case of less competition to gain surplus profit. The cumulative surplus profit caused by the instability of level of competition is the area enclosed by "RMP" curve and "RMP 2" curve.

Results of this section reveal that under the competitive bidding system, the "Price Competition Feedback Structure" will perform the effect of free market economy. But the uncertainties of the market environment block the perfect economic efficiency and still provide bidders a room to make surplus profit.

4.2 On Assumption that Cost Difference is Considerable

As mentioned earlier, under normal market competition, contractors can win awards by reducing expected profit and reducing cost. But when competition is intensified to a certain extent, eventually the market price will approach bidders' cost and the profit will be seriously reduced. Thus, contractors still have to face the issues of innovation and cost reduction, so as to pursue continuous development. A "Firm Grow Up Feedback structure" is formed if contractors continuously improve their practices as follows.

When bidders are able to reduce their costs, bidding prices will be lowered and opportunities to win projects increased. Afterwards contractors can acquire more resources to develop their competence, along with a sound management system and execution techniques, cost and bidding price can be further reduced to enhance competitiveness. Thus, a reinforcing feedback loop which guides contractors to the directions for continuous development, is formed and called "Firm Grow Up Feedback structure" (see Figure 3). Because bidders' cost renovation cannot be achieved immediately, there is always a time delay between the investment in R&D and the execution of cutting cost.

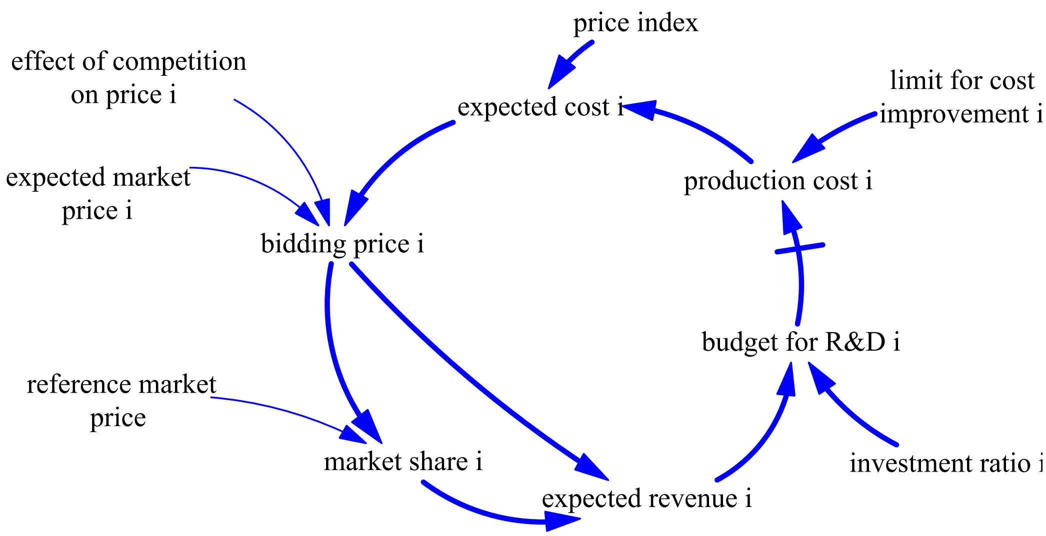

Figure 3. Firm Grow Up Feedback structure

Effect of Firm Grow Up Feedback structure on the Market Price

Figure 4 shows the trends of market price when most firms reduce their costs as time proceeds. "RMP" curve represents the tendency of market price that varies with time, "EVC" curve represents the variable cost of the contractor with the best cost advantage, "EVC 2" curve represents the variable cost of contractor in general, and "EVC 3" curve represents the variable cost of the contractor who never reduce its 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 follow the general pace of cost reduction, or does not reduce its cost at all (as shown in the "EVC 2" and "EVC 3" curves in Figure 4), in the long run, this contractor will surely lose its competitiveness.

The results in this section reveal that the ideal competitive bidding system is expected to contain two economic feedback structures, "Price Competition Feedback structure" and "Firm Grow Up Feedback structure", in the construction market. Theoretically these two structures together would function in accordance with the spirit of free market competition, and are able to promote continuous growth of construction firms and industry as well as create social welfares.

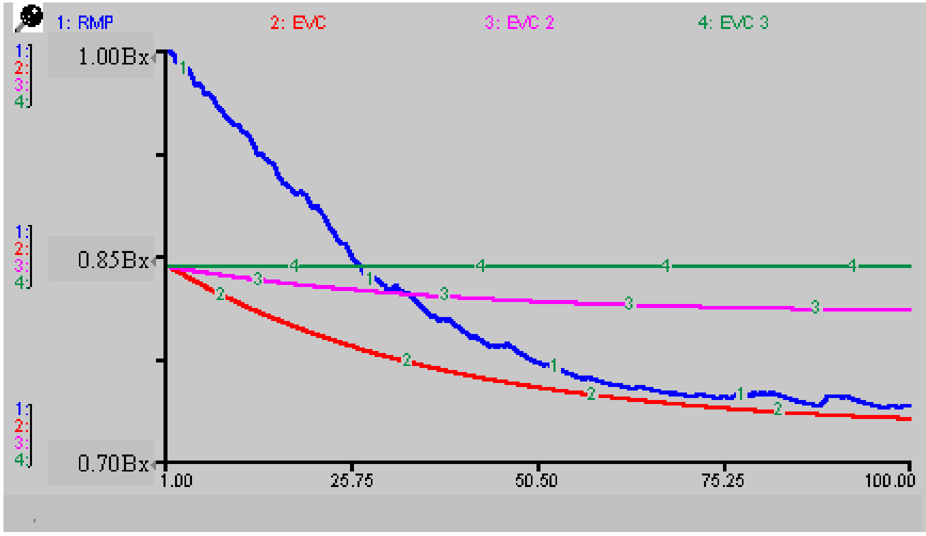

Figure 4. The Trend of Market Price When Contractors' Cost Varies

5. The Hidden Adverse Feedback structure

The competitive bidding system assumes that the bidding process will be independent from any sort of pressure (political, social, economic). Its objectivity is ensured because price is the sole criteria for evaluating bids (Herbsman and Ellis, 1992). However, owner may award the bid to a contractor with an abnormal low-bid. In general, contractors submit an abnormal low-bid due to insufficient professionalism or cursory cost estimation. 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. Therefore, it would not form the main cause of market failure. The main factor that might cause serious problems to the construction market should be contractors' deliberate low-bidding behavior.

When contractors have a possibility to gain BCR through cutting corners and claims, they would adopt some opportunistic strategies by cutting down the bid price. A reinforcing loop with adverse effects is thus formed, in which contractors manipulate construction biddings through malign price reduction. This "Opportunistic Bidding Feedback Structure", is shown in Figure 5.

This research assumes that *"expected beyond-contractual reward" (EBCR)* is the jetton on which contractors rely to lower the bidding price. Therefore, the decision function of contractors' pricing is transformed from the equation of $MAX\ [(EMP_i + ETC_i * ECP_i), EVC_i]$ into Equation *(6)*.

$$BP_i = MAX\ [(EMP_i + ETC_i * ECP_i), EVC_i - EBCR_i] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

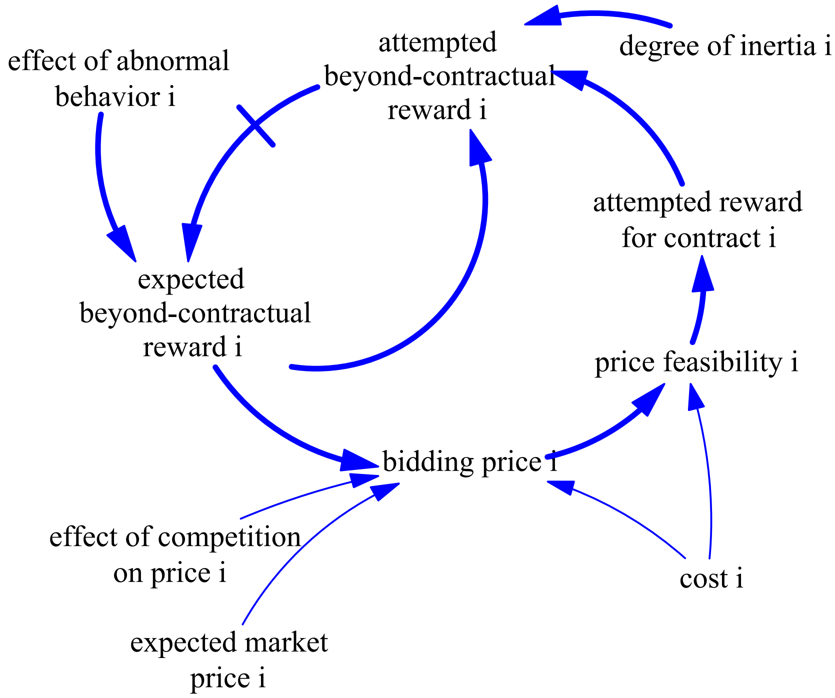

Figure 5. Opportunistic Bidding Feedback structure

Contractors' *EBCR* is affected by "*attempted beyond-contractual reward*" *(ABCR)* and "*effect of abnormal behavior*" *(EOAB)*, as explained as follows:

ABCR represents the BCR that contractors attempt to obtain, and consists of two categories of variables. The first catogory contains *"attempted reward for contract"* (ARC) and "*price feasibility"* (PF). *ARC* is the amount of money that contractors plan to gain to make up the sacrifice in the tender stage. PF regards the level of tendency for contractors to conduct abnormal bidding behavior, and is defined as *BP/EVC*. If *BP/EVC*＜1, then it means the contractors are faced with loss, forcing them to pursue BCR to compensate the loss. The lower the value of *BP/EVC*, the higher the *ARC* of contractors. If *BP/EVC*＞1, the bidding price covers part of the contractors' profit, so the contractors have no need to look for *ARC*.

The second category of variables that influence *ABCR* is the contractor's *"degree of inertia" (DOI)* for *EBCR*, which regards the fact that, when contractors have successfully gained BCR in the past, they tend to repeat the same behavior to maximize their profit no matter if the award price is reasonable or not.

Since owners have control over the project performance, contractors' *ABCR* can not be completely fulfilled. Even most contractors intend to gain BCR, the actual BCR would be discounted and varied due to different strictness of owners' construction management over the project. To describe this situation, a discounted impact factor *"effect of abnormal behavior" (EOAB)* on contractors' *ABCR* was configured in the model, where *EOAB* ranges from 0 to 1. Hence the BCR actually gained by the contractor is *ABCR* * *EOAB*. When *EOAB* equals 1, it means that BCR gained by contractors equals *ABCR*; in other words, the owner's construction management is completely ineffective. Therefore the lower the *EOAB*, the better the construction management performed by the owner.

Both *"expected beyond-contractual reward" (EBCR)* and *"reference market price" (RMP)* described in previous section are variables that dynamically change with previous human experiences and time. The *EBCR* are directly influenced by previous BCR; and contractors make adjustments according to the discrepancy between *EBCR* and BCR for each project. Thus, a "First-order linear negative feedback system" was developed to model the *EBCR*.

Effect of Opportunistic Bidding Feedback Structure on the Market Price

In the aforementioned model, it is assumed that contractors who attempt to gain compensation eventually obtain 70% of the rewards (*EOAB* equals 0.7). During the simulation, though the effects of free market competition remained in the model, the market price quickly dropped and becomed lower than the contractors' cost limit(Figure 6). This would force contractors unwilling to pursue BCRs lose competition advantages. For contractors who adjust their bids after considering BCR, even though the market price seems lower than the cost limit, the total reward, "RMP + EBCR" , still covers the cost (Table 2). It can be hereby inferred that the opportunistic bidding of "win the bid with low price and then look for BCR" by contractors under competitive bidding system grounds in rational decision strategies.

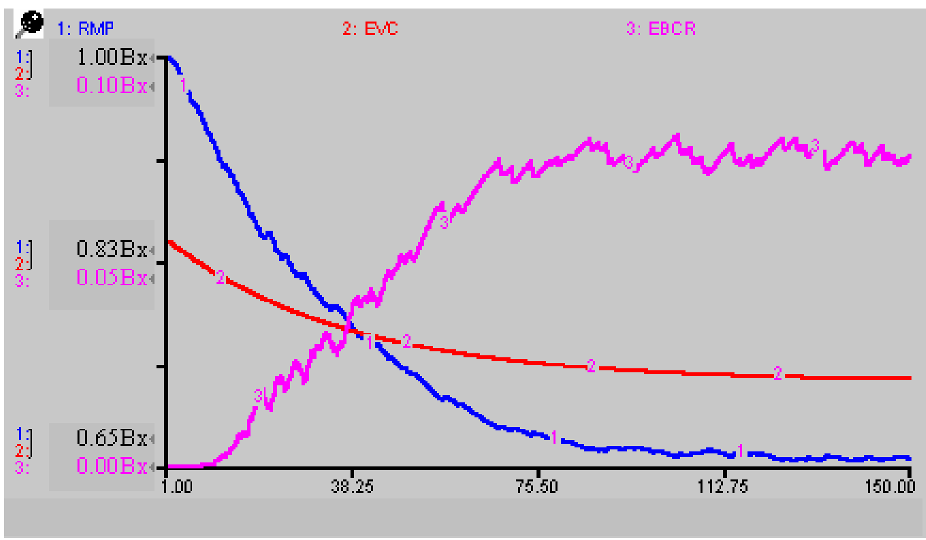

Figure 6. The Trend of Market Price in Opportunistic Bidding Feedback structure

In cases without regard to BCR, the competitive bidding system assumes that the bidding prices of all contractors reflect their costs, and they abide by the contract and quality requirements. However, this research found that there is an adverse Opportunistic Bidding Feedback Structure hidden within the competitive bidding system and contractors' pricing behaviors. When excessive room for BCR exists in the market, contractors who bid opportunistically will gain higher possibility to take more market share. Consequently contractors raise their expectations for BCR and tender with even lower price in the future construction projects. The aforementioned process results in a "Reinforcing Feedback Process" that constantly intensifies the effect. The fact that market price eventually reaches an equilibrium level lower than the contractors' cost will force all contractors in the market to survive upon BCR. Furthermore, awarding with an unreasonably low price would severely cut down the profit and keep contractors from investing in R&D and paralyze "Firm Grow Up Feedback structure". It is therefore deduced that disorder of market price and stagnated growth of contractors are not incidental, but a systematic problem that needs to be further studied and remedied.

Table 2. Numerical Analysis of the Impact of Opportunistic Bidding Feedback structure

Time Unit	Market Price (RMP)	Contractor's Cost Limit (EVC)	Expected BCR (EBCR)	Total Reward Gained by Opportunistic Contractors (RMP+EBCR)
Initial	10,000	8,415	0	10,000
10	9,143	8,126	16	9,159
20	8,491	7,907	140	8,631
30	7,944	7,742	290	8,234
40	7,556	7,616	409	7,965
50	7,246	7,521	531	7,777
60	6,981	7,449	647	7,628
70	6,805	7,395	706	7,511
80	6,695	7,353	757	7,452
90	6,649	7,322	746	7,395
100	6,598	7,298	782	7,380
110	6,614	7,281	742	7,356
120	6,587	7,267	758	7,344
130	6,550	7,257	775	7,325
140	6,557	7,249	755	7,312
150	6,558	7,243	758	7,316

6. Sensitivity Analysis of Feedback structures

Sensitivity analysis is used to determine how "sensitive" a model is to changes in the value of the parameters and structure of the model (Breierova and Choudhari, 1996). This section primarily focuses on the sensitivity of key parameters in the three feedback structures and investigates the relative sensitivity of each structure when all of the three feedback structures are functioning.

6.1 Price Competition Feedback Structure

Price Competition Feedback structure is constructed on the basis that bidders adjust their prices by the perception of level of competition. Thus, competition level is the most important parameter representing the strength of Price Competition Feedback structure. In the simulation model, it was initially set up that general bidders assume the reference number of competitors is 7, however when it exceeds 7, the competition in pricing will be intensified. Therefore, the parameter, *PNC,* was set as RANDOM (8-13), RANDOM (5-10), and RANDOM (3-8) to simulate the market price trends under three distinctive market competition levels, very keen, general, and very slack.

The computer simulation showed that, the market prices under different competition levels still can drop to the price level lower than contractor's cost limit despite the price level of the very slack competition market is moved up (see Figure 7. where the curve "RMP" stands for general market circumstance, "RMP2" stands for very keen competition level, and "RMP3" stands for very slack competition level).

Furthermore, when the market is truly on competion and contractors have to take BCR into account for pricing decision (in cases of *PNC* at least more than 5 in this research), even under different competition levels, all market prices eventually gather at the same equilibrium price that is lower than contractors' cost limit. The only difference is the gathering speed, which was manifested by the different slopes of the curves (see Figure 8.). In this situation, changing the competition level impacts the equilibrium of market price insignificantly.

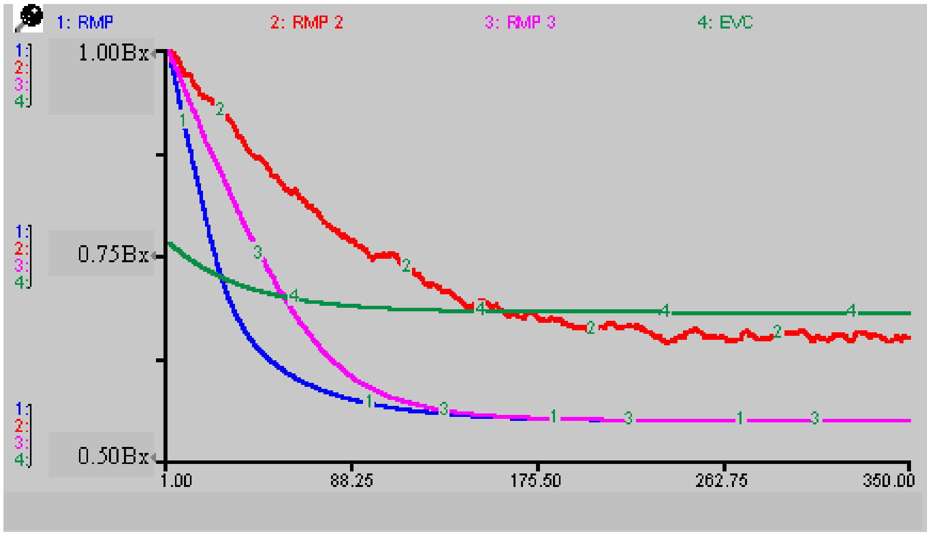

Figure 7. Sensitivity Analysis of Price Competition Feedback structure (a)

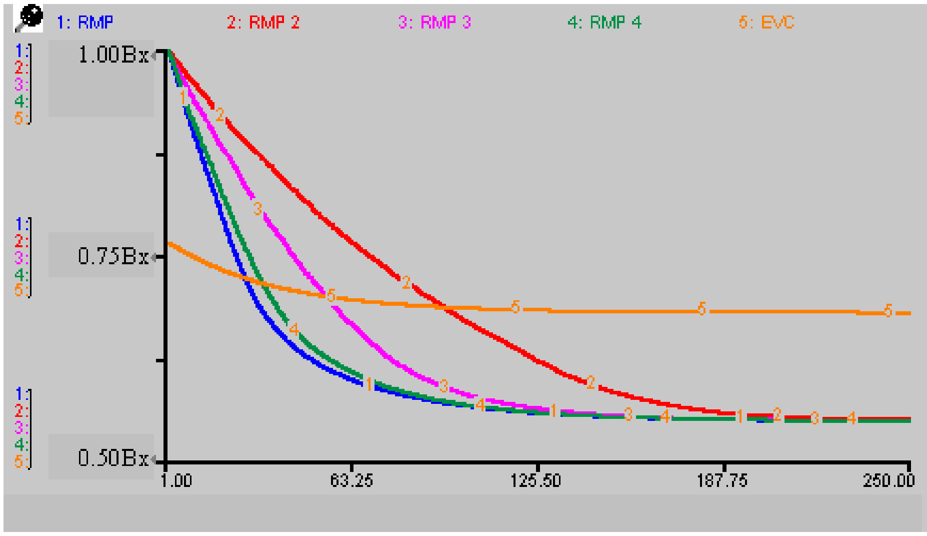

Figure 8. Sensitivity Analysis of Price Competition Feedback structure (b)

6.2 Firm Grow Up Feedback Structure

Firm Grow Up Feedback structure is developed to describe firms' cost renovation. Thus, the "level of renovation" is the most important parameter regarding the strength of Firm Grow Up Feedback structure. Generally speaking, it is hard for contractors to make significant improvement in a short time, and the breadth of improvement is also limited. This research assumed that bidders are able to lower their cost to 60% of the government's budget within 6 years, and it is the limit of their cost renovation. Figure 9 shows the trends of market prices when most firms reduce their costs as time proceeds. The curve "EVC 2" represents the variable cost of the contractor with the fastest cost renovation, and the curve "RMP 2" represents the corresponding tendency of market price that varies with time. The curve "EVC" represents the variable cost of contractor with average level of cost renovation and "RMP" curve represents the corresponding tendency of market price that varies with time.

The results reveal that if the Opportunistic Bidding Feedback Structure exists in the construction market, in most cases, Firm Grow Up Feedback structure is almost invalid in relation to Opportunistic Bidding Feedback structure. Even if contractor's cost renovation is extremely fast, as long as Opportunistic Bidding Feedback structure exists, it will always dominate the Firm Grow Up Feedback structure, and the final equilibrium market price will be lower than contractor's cost limit.

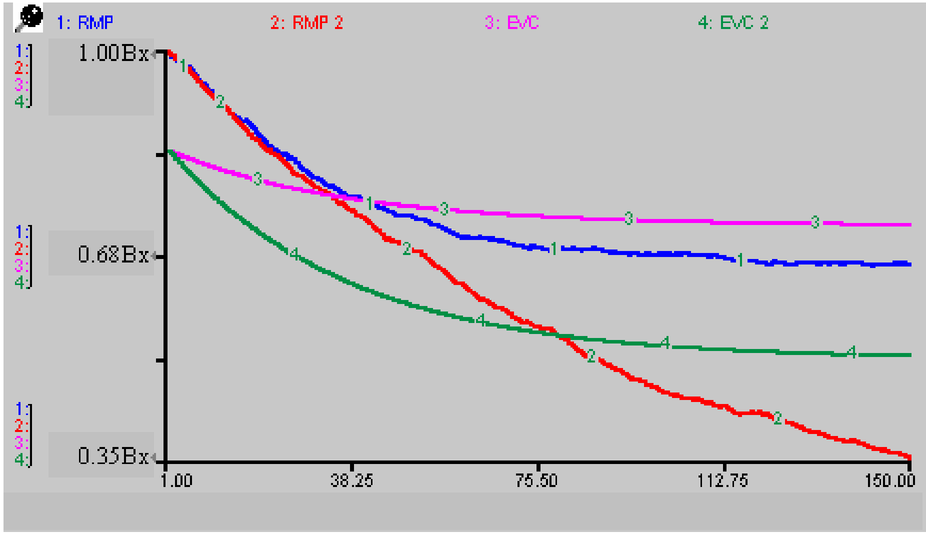

Figure 9. Sensitivity Analysis of Firm Grow Up Feedback structure

6.3 Opportunistic Bidding Feedback Structure

How BCR influence the equilibrium of market price is analyzed by introducing the impact factor, *EOAB*. And how good the owners excute construction management would directly affect the existence or amount of BCR, too. As aforementioned, the lower the *EOAB*, the better the construction management performed by the owner. Therefore the lower the *EOAB*, the less the probability that contractors obtain BCR, and hence the lower the expected BCR; and vice versa. The *EOAB* is set as 0.7, 0.4, and 0.1 to simulate and derive the trends of market prices respectively.

It is found that, under the same competition and cost conditions, different BCR would result in different equilibrium market price. As the *EOAB* is smaller, the market price becomes more reasonable. Even, when *EOAB* is below a certain degree, hopefully the market price can be corrected to a level that matches contractors' cost (see Figure 10). This result reveals that when BCR is considered in the contractor's pricing decision, Opportunistic Bidding Feedback structure will be the most critical factor that affects market price.

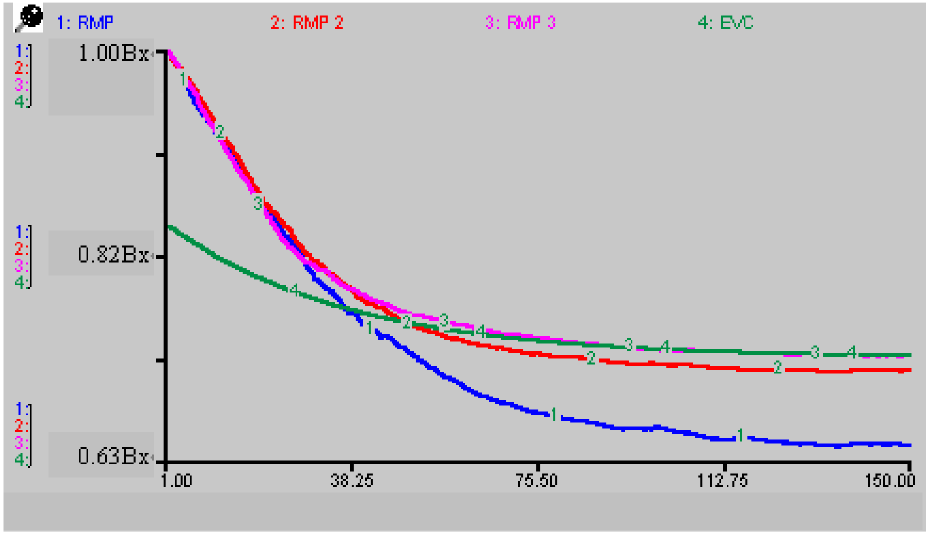

Figure 10. Sensitivity Analysis of Opportunistic Bidding Feedback structure

Through the discussions in this section, it is found that the intended free market competition mechanisms pursued by the competitive bidding system can only be effective when Opportunistic Bidding Feedback structure is restrained; otherwise, the Price Competition and Firm Grow Up Feedback structure will not properly function. To promote a fair and prosper construction industry, means to control the function of the Opportunistic Bidding Feedback structure should be effectively devised and executed by the government and industry.

7. Conclusions

The construction market is a system, which consists of enormous amounts of variables and feedbacks. The system behaviors and the underlying causes are very complex and far beyond the comprehension of human's mental capability.

Unusual to the qualitative methodologies widely adopted in the previous construction market research, this paper presented a SD model to analyze the competitive bidding system of the construction market. In addition to the more comprehensive viewpoint of analysis, this paper also explored the hidden dynamics of construction market by numerical simulation and sensitivity analysis.

The SD model consists of three feedback structures; two of them are general economic feedback structures, namely "Price Competition" and "Firm Grow Up"; the third feedback structure, "Opportunistic Bidding", is usually unperceived and would disorder the construction market.

Through simulation analyses of the relative sensitivity of each feedback structure, it is discovered that the "Opportunistic Bidding" is a self-reinforcing vicious cycle, and once it is activated, the free market competition mechanism established by Price Competition and Firm Grow Up feedback structures will be adversely impacted.

In order to ensure the proper functions of the free market competition mechanism, managerial policies focusing on control of the effects caused by Opportunistic Bidding Feedback Structure is necessary. Those policies may include the implementation of a more robust price evaluation system to screen out the deliberate abnormal low-bids, and the initiation of more prudent and comprehensive contracts and construction management system to reduce the potential beyond-contractual reward.

Despite some significant feedback structures were discovered and deduced in this research, boundary of the system needs to be more extended to explore relative issues, such as effects of "best value contracting" on contractors' pricing and market price, and methods for parameter estimation of contractors' pricing decision variables, so as to further enhance the depth and width of market economics research.

8. Reference

Assaf SA, Bubshait A, Aitah R. 1998. Bid-awarding systems: an overview. *Cost Engineering* **40(8)**: 37-39.

Ayer AJ. 1952. *Language, Truth, and Logic*. New York: Dover.

Breierova L, Choudhari M. 1996. *An Introduction to Sensitivity Analysis*. Massachusetts Institute of Technology.

Capen EC, Clapp RV, Campbell W. 1971. Competitive bidding in high risk situations. *Journal of Petroleum Technol.* **23(6)**: 641-653.

Carr RI. 1982. General bidding model. *Journal of Construction Division*. **108(4)**: 639-650.

Carr RI. 1983. Impact of number of bidders on competition. *Journal of Construction Engineering and Management*. **109(1)**: 61-73.

Clough Richard H. 1994. *Construction Contracting*. 6th Ed, New York: John Wiley & Sons.

Cohen A. 1961. *Public Construction Contract and the Law*. New York: F. W. Dodge.

Crowley LG., Hancher DE. 1995a. Evaluation of competitive bids. *Journal of Construction Engineering and Mangement* **121(2)**: 238-245.

Crowley LG., Hancher DE. 1995b. Risk assessment of competitive procurement. *Journal of Construction Engineering and Management* **121(2)**: 230-237.

De S, Fedenia M, Triantis AJ. 1996. Effects of competition on bidder returns. *Journal of Corporate Finance* **2**: 261-282.

Doyle WJ, DeStephanis A. 1990. Preparing bids to avoid claims. *Construction Bidding Law*. R.F. Cushman and W.J. Doyle, John Wiley & Sons, Inc. New York, N.Y., 17-45.

Drew D, Skitmore M, Lo HP. 2001. The effect of client and type and size of construction work on a contractor's bidding strategy. *Building and Environment*. **36**: 393-406.

Fayek A. 1998. Competitive bidding strategy model and software system for bid preparation. *Journal of Construction Engineering and Management* **124(1)**: 1-10.

Friedman L. 1956. A competitive bidding strategy. *Operation Research*. **4**: 104-112.

Gates M. 1976. Gates' bidding model—a Monte Carlo experiment. *Journal of Construction Division*. **102(4)**: 669-680.

Gransberg DD, Ellicott MA. 1996. *Best Value Contracting: Breaking the Low-Bid Paradigm*. AACE TRANSACTIONS.

Grogan T. 1992. Low bids raise hidden costs. *Engineering News-Record* **228(13)**: 30-31.

Henriod EE, Lanteran JM. 1988. *Trend in contracting practice for civil works*. Task Force on Innovative Practice, World Bank, Washington, D.C.

Herbsman Z, Ellis R. 1992. Multiparameter bidding system-innovation in contract administration. *Journal of Construction Engineering and Management* **118(1)**: 142-150.

Ho SP, Liu LY. 2004. Analytical model for analyzing construction claims and opportunistic bidding. *Journal of Construction Engineering and Management* **130 (1):** 94-104.

Ioannou PG., Leu SS. 1993. Average-bid method—competitive bidding strategy. *Journal of Construction Engineering and Management*. **119(1)**: 131-147.

Rankin JH, Champion SL, Waugh LM. 1996. Contractor selection: qualification and bid evaluation. *Canadian Journal of Civil Engineering* **23**: 117-123.

Sterman JD. 2000. *Business dynamics—systems thinking and modeling for a complex world*, International edition, McGraw-Hill, Inc..

Taiwan Construction Research Institute. 2000. Gloomy 2000 for construction companies—results of an industry-wide questionnaire survey in Taiwan. *Construction News Record* **19(12)**: 22-31. (in Chinese)

Wang WC. 2004. Supporting project cost threshold decisions via a mathematical cost model. *International Journal of Project Management*. **22 (2)**: 99-108.

Winch G.M. 2000. Institutional reform in British construction: partnering and private finance. *Building Research and Information* **28(2)**: 141-155.

Yang JB, Wang WC. 2003. Contractor selection by most advantageous tendering approach in Taiwan. *Journal of the Chinese Institute of Engineers*. **26(3)**: 381-387.

9. Notation

The following symbols are used in this paper:

AP	=	award price;
ABCR	=	attempted beyond-contractual reward;
ARC	=	attempted reward for contract;
BP	=	bidding price;
DOI	=	degree of inertia;
ECP	=	effect of competition on price;
EMP	=	expected market price;
EOAB	=	effect of abnormal behavior;
EBCR	=	expected beyond-contractual reward;
ETC	=	expected total cost;
EVC	=	expected variable cost;
PF	=	price feasibility;
PNC	=	perceived number of competitors;
RMP	=	reference market price;
RNC	=	reference number of competitors;
SECP	=	sensitivity of ECP.