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A Zero-Cost Collar Option Applied to Materials Procurement Contracts to Reduce Price Fluctuation Risks in Construction

H. L. Yim, S. H. Lee, S. K. Yoo, J. J. Kim

***Abstract*—**This study proposes a materials procurement contracts model to which the zero-cost collar option is applied for heading price fluctuation risks in construction.The material contract model based on the collar option that consists of the call option striking zone of the construction company(the buyer) following the materials price increase andthe put option striking zone of the material vendor(the supplier) following a materials price decrease. This study first determined the call option strike price X_c of the construction company by a simple approach: it uses the predicted profit at the project starting point and then determines the strike price of put option X_p that has an identical option value, which completes the zero-cost material contract.The analysis results indicate that the cost saving of the construction company increased as X_c decreased. This was because the critical level of the steel materials price increasewas set at a low level. However, as X_c decreased, $X_p$of a put option that had an identical option value gradually increased. Cost saving increased as X_c decreased. However, as X_p gradually increased, the risk of loss from a construction company increased as the steel materials price decreased. Meanwhile, cost saving did not occur for the construction company, because of volatility. This result originated in the zero-cost features of the two-way contract of the collar option. In the case of the regular one-way option, the transaction cost had to be subtracted from the cost saving. The transaction cost originated from an option value that fluctuated with the volatility. That is, the cost saving of the one-way option was affected by the volatility. Meanwhile, even though the collar option with zero transaction cost cut the connection between volatility and cost saving, there was a risk of exercising the put option.

***Keywords*—**Construction materials, Supply chain management, Procurement, Payment, Collar option

I. Introduction

THE construction project's profitability is directly affected by the accuracy of cost estimation at the planning stage[4]. Given that materials and equipmentsconstituteasignificant proportion (i.e., 60% in 1979)[5] of the total construction project cost [4], it depends on the contractors' ability to take off the quantity of resources correctly and obtain exact price of those [17]. However, due to the materials price fluctuation, they have experienced difficulties to do this. Moreover, the materials demand from the construction industry occurs in a short-termproject-based manner[23]. Compared to the other manufacturing industries that first produces and then sells, the construction industry is based on order-to-delivery process. Furthermore, the moment to order and pay for materials can vary according to delivery methods. For this reason, construction companies may order materials after the client approve specifications. Due to this unique context, an increase in the construction cost due to the materials price fluctuation is directly connected to the decrease in profits for the construction company unless payment methods to remunerate the lost (i.e. cost-plus-fee) are agreed in contract. However, this kind of payment method can increase the unpredictability in terms of budget for the client: in other words, risk is just passed to the other side. Regarding the situation discussed so far, a method is required that can hedge risks derived from the material price fluctuation. In this aspect, Ng et al.[23], suggested that the materials supplier and buyer should form a dynamic relationship that can support strategic flexibility. According to them, the option theory is likely to support the both sides: buyers, contractors, can obtain flexibility to minimize inventory cost and hedge price fluctuation; and materials suppliers can diversify their price risks and stabilize production schedule. However, such flexibility causes some costs to the related parties[2]. Especially, a one-way option contract, either from supplier to demander or from demander to supplier, option buyer who participated passively in the contract should pay additional option transaction cost entailed by an uncertain future.Unlike financial organizations, construction company and materials suppliers are not specializing in risky investment.In order to provide practical method to hedge risks, alternative options without additional costs need to be presented. This study proposes a materials procurement contracts model to which the zero-cost collar option [6, 16, 20] is applied for heading price fluctuation risks in construction. Given that the risk hedge can cause inequality among parties, this issue should be approached in the boundary of supply chain management (SCM) in which relationship between supplier and buyer is regarded important.

H. L. YimDepartment of Sustainable Architectural Engineering, Hanyang University, Seoul, Korea (phone: 82-2-2220-0307, fax: 82-2-2296-1583, e-mail: o_os@nate.com).

S. H. LeeDepartment of Sustainable Architectural Engineering, Hanyang University, Seoul, Korea.(e-mail: siegfried_sun@hotmail.com)

S. K. YooDepartment of Sustainable Architectural Engineering, Hanyang University, Seoul, Korea.(e-mail:james_yoo@hotmail.com)

J. J. Kim, Department of Architectural Engineering, Hanyang University, Seoul, Korea (e-mail: jjkim@hanyang.ac.kr).

II. Supply Chain Management and Materials Procurement Literature

In general, suppliers experience difficulties in determining the price and amount of products due to market uncertainty.There have been various studies focusing on contract types that can secure flexibility to reduce the risk from such uncertainty. Lian et al.[19] suggested a specific supply contract model in which a buyer receives discounts for committing to purchase in advance. The option theory applied in this study was first introduced for securing flexibility in response to the future uncertainty of financial assets. The study is an evolved version of previously mentioned literature in that applying option theory to the supplier-buyer contract relationship supports flexibility.Barnes-Schuster et al.[2] suggested a generic framework for a buyer-supplier system applying an option theory, arguing that the system should secure sufficient flexibility in order to promptly respond to the market needs. They mentioned that backup-agreement, two-period, quantity-flexibility contracts, as well as pay-to-delay arrangements, are special types of contracts that use options. That is, suppliers and buyers can form diverse types of contracts by appropriately making use of option theory.Construction industry hasalso focused on the effective management of material procurement from the viewpoint of SCM. The research can be classified as follows: fundamental research [28], management systems [4, 5], partnerships [18], material delivery [1], and supplier selection [7].However, few studies have examined how to bring flexibility to the material price fluctuation in a relationship between the material supplier and the construction company.In fact, Ng et al. [23] analyzed long-term contracts with price caps related to the construction material supply by making use of real options. The material contract suggested in this paper is similar to a financial call option, in that the buyer exercises the option when the materials price is higher than the strike price. This type of contract enables the material vendor to establish an effective materials production plan so that it can conclude a long-term contract with the demander while increasing its shares of the market. Moreover, the construction company can have the flexibility to limit the material price fluctuation within a certain range.Nevertheless, in the case of those one-way option contracts, the option buyer, that is, the construction company, should pay the option price to the option seller of the material supplier. As a result, the construction company can be reluctant in option contracts, due to the additional expenditure. Collar option has been mentioned as an alternative method to cope with problems due to the additional cost (i.e. Fuller [16]; Linden [20]).

III. Theoretical Background Of Collar Option

An option is a security giving the right to buy or sell an asset, subject to certain conditions, within a specified period of time. The most common types of options are a call option and a put option. A collar option involves buying an out-of-the-money call and selling an out-of-the-money put of equal value with the same expiration date[20]. So, a collar allows the utility a higher level of sophistication by buying downside and selling upside protection, with a designated amount within either side that does not trigger any action for the both parities [16].The collar option is often used for currency trading in financial sectors. Linden [20] examined how to reduce risk in a foreign currency transaction by using a zero-cost currency option collar as a hedging tool.Moreover, Bettis et al. [6] used a collar option for flexibly hedging the assetprice volatility risk of company shareholders at zero-cost. There are studies that examined the application of the collar option in hedging the realprice volatility risk. Carter et al. [10] investigated whether the collar option could be used for hedging fuelprice volatility risk in the airline industry and reported that the collar option had the advantage of zero cost, while keeping the option risk at a proper level.It can be assumed that the price fluctuation risk can be reduced in constructionif the collar option is introduced to a materialprocurementcontract model between construction companies and material vendors, since the increment of materials price is kept below the strike price of the call option.The material vendor can obtain a stable demander, since it can conclude a long-term contract with the collar option until the termination period. Moreover, it can acquire additional profit, since the decrement of the materials price is kept above the strike price of the put option.

IV. Materials Procurement Contract Model Introducing Collar Option

A. Proposed framework

The material contract model based on the collar option that consists of the call option striking zone of the construction company(the buyer) following the materials price increase andthe put option striking zone of the material vendor(the supplier) following a materials price decrease. Fig. 1 is the concept of a material procurement contract model introducing the collar option.If the materials price at t=0 is S, S is located between the put option strike price (X_p) and the call option strike price (X_c). The magnitude of the increment of materials price (D_c) and decrementof materials price (D_p) can differaccording to the probabilities of price increases and decreases. That is, $D_c > D_p$ when the overall materials price fluctuation has an upward trend, and $D_c < D_p$ when the fluctuation has a downward trend.In order to complete the zero-cost material procurementcontract model, the X_c and X_p values to be determined should equate the option value with the call option and put option. Due to the unique characteristics of a construction industry that produces on the order, the construction company obtains profits from the difference between the contract price and the construction cost.Because the contract price is fixed, the materials price fluctuation is a very sensitive issue for the construction company.Hence, this study first determined the call option strike price X_c of the construction company by a simple approach: it uses the predicted profit at the project starting point and then determines the strike price of put option X_p that has an identical option value, which completes the zero-cost material contract. In the material procurement contract model suggested in this study, it is assumed that the contract is made at the level of a construction company rather than at the level of a project as all its projects that are undergone during the option contract period are comprehensively contained in the supply contract with the material vendor. The construction company can limit the increase in the materials price below a certain level, while the material vendor can secure a stable demander with a construction company level requirement instead of a project-level requirement. This contributes to increasing the materials productivity because the supplier can establish an effective production plan.

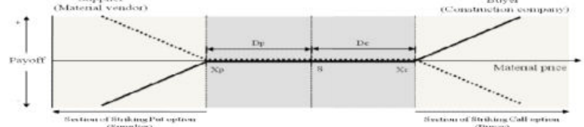

Fig. 1 Concept of a material procurement contract model introduction the collar option

B. Approach for Setting up the Striking Price

This study determines the call option strike price of a construction company by using profit from its projects during the option contract. As the project profitare generated from allocating various resources such as human resource and materials, the project profits can be distributed proportionately based on the resource input.Taking this under consideration, the profit that occurs from putting in materials can be calculated. All in all, the maximum calloption strike price is the sum of the current materials price S and the profit from unit materials(P_{um}). That is, the upper bound to $X_c(D_c)$ is determined by P_{um}. The relation is described in (1).

$$X_c \leq S - P_{um} \quad (1)$$

It is possible that the total profit will be positive, even when Dcis higher than P_{um}, since cost reduction can be achieved by a price cut in other materials or by advanced construction techniques. However, the availability of a cost cut during the construction period is uncertain. Hence, it is reasonable to set Dc below P_{um}.At a single project level, profit (P) is the difference between the contract price (CP) and the estimate at completion(EAC), as written in (2). Since CPis determined at the beginning, P fluctuates with the changes in the EAC as follows:

$$P = CP - EAC \quad (2)$$

The option contract case in this study contains multiple projects that have already been initiated. Hence, the construction project's EAC is different according to the project's progress. From the view of earned value management (EVM), the EAC can be determined as below [3]:

$$EAC = ACWP + (BAC - BCWP)/CPI \quad (3)$$

$$CPI = BCWP/ACWP \quad (4)$$

EAC : Estimate At Completion
ACWP : Actual Cost for Work Performed
BAC : Budget AtCompletion
BCWP : Budgeted Cost for Work Performed
CPI : Cost Performance Index

The EAC computed from (3) and (4) is plugged into (2) to obtain P. When the materials requirement is M_r during the option contract and the unit materials price is $S_s$at the option's beginning time, the profit (P_m) occurring from $M_r$can be obtained from the following (5).

$$P_m = P \times \frac{(BAC - BCWP)/CPI}{EAC} \times \frac{M_r \times S_s}{(BAC - BCWP)/CPI}$$
$$P_m = P \times \frac{M_r \times S_s}{EAC} \quad (5)$$

However, there are multiple projects that the construction company conducts during the option contract period, as depicted below. For example, as Project A starts at time ta and Project B starts at t_b, the progress of the two projects are completely different at t_s when the option contract is initiated. Some projects can be completed before t_e, and others can remain unfinished. Therefore, the variables in (5) varyaccording to projects.

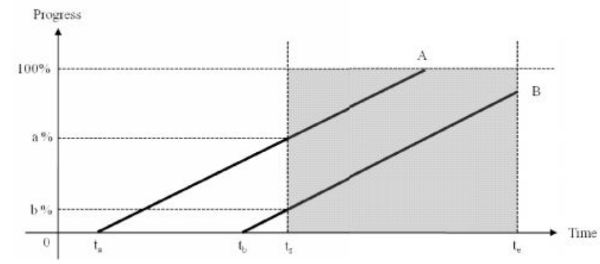

Fig. 2 Diverse projects with different progress rate during the option contract period

Assuming that the construction company has n projects at t_s, the total profit (P_{rm}) occurring from the materials in these projects can be expressed as (6).

$$P_{rm} = \sum_{k=1}^{n} \left(P(k) \times \frac{M_r(k) \times S_s}{EAC(k)} \right) \quad (6)$$

Accordingly, the P_{um} that determines the Dc can be written as (7). P_{um} is used to determine the X_c in (1), which is subsequently used to determine the X_p which has an identical option value.

$$P_{um} = P_{rm} / \sum_{k=1}^{n} M_r(k) \quad (7)$$

V. Case Study for Validation

In order to illustrate the practicability of the proposed material procurement contract model introducing the collar option, this paper apply it into a case of steel materials. The fluctuation in steel price is relatively larger than that in other construction materialsand its share of the total material cost is very high.As a result, an increase in the steel price has a large impact on the profits reduction of a construction company. For the analysis, it was assumed that a construction company concluded a one-year material procurementcontract with a steel materials supplier, beginning in January 2008. Until the termination date in December 2008, the steel materials supplier has a stable demander and the construction company can limit the steel materials price below the strike price of the call option. However, in cases where the option can be exercised only at the time of contract termination, it is hard to effectively manage the materials fluctuation that occurs during the construction period, which decreases the effectiveness of the material procurement contract. In order to solve this problem, this study sets up an option structure following the American option, which allows the exercise of the option before the end of contract [22]. In reality, materials price data are in a discrete form, different from that of regular financial asset datawhich are continuous. Hence, the binomial lattice model was used for estimating the option value without assuming continuous time such as in Black-Sholes model.

A. Data sets

This study analyzed 19 projects of construction company A for the purpose of examining the effect of a collar option-based material procurement contract between a construction company and steel supplier. The analysis data included the contract price (CP), duration, actual cost for work performed(ACWP), budget at completion(BAC), and budgeted cost for work performed (BCWP). These were obtained from the budget plan and statement of items from each project. The estimate at completion(EAC) was computed by calculating the cost performance index(CPI).Especially for the steel amount used during the option period(M_r), the monthly usage was calculated based on the initially planned construction type and the progress chart of the sample projects.

TABLE I
SAMPLE PROJECT LIST

P/J No.	CP($)	Duration (months)	BAC ($)	ACWP ($)	BCWP ($)	EAC ($)	M_r (ton)
1	85,300,000	27	63,943,805	2,947,809	2,915,838	64,644,943	3,947
2	104,651,000	28	81,868,428	21,384,033	22,088,102	79,258,834	5,068
3	137,150,272	26	111,323,386	2,493,644	2,538,173	109,370,345	7,861
4	72,014,850	26	55,839,565	8,962,250	9,381,047	53,346,728	4,616
5	94,146,543	29	70,903,483	1,446,431	1,439,341	71,252,761	3,758
6	134,789,270	33	97,776,545	10,305,648	11,038,972	91,281,203	6,155
7	85,255,153	40	76,860,045	3,597,050	3,627,794	76,208,688	2,782
8	76,539,570	27	57,723,682	12,393,275	13,126,365	54,499,888	5,416
9	168,705,337	31	125,825,457	9,688,560	9,625,647	126,647,846	8,443
10	102,617,657	33	82,983,843	7,725,796	8,007,941	80,060,060	4,339
11	193,869,115	33	155,941,475	25,917,473	26,369,703	153,267,138	13,501
12	140,908,951	30	127,801,173	14,467,093	16,499,131	112,061,137	9,306
13	149,338,401	31	139,048,925	11,262,963	11,332,487	138,195,865	9,705
14	107,468,108	28	80,521,297	3,631,510	3,639,563	80,343,152	5,720
15	47,335,363	24	35,678,659	10,325,404	10,857,016	33,931,659	2,240
16	105,512,000	26	63,580,338	19,226,694	19,786,201	61,782,437	4,628
17	250,287,000	36	212,927,553	25,274,501	26,339,138	204,320,942	18,727
18	60,950,350	34	44,889,971	2,442,014	2,446,503	44,807,604	1,989
19	373,902,523	41	310,327,843	44,438,947	45,028,570	306,264,281	13,503

Table II summarizes the monthly steel amount required for 19 projects during the analysis period. The monthly steel amount can change as the construction progresses on. However, if the approximate monthly steel amount is determined, as in Table II, the material vendor can also establish an efficient materials production plan. As a result, the materials productivity increases, which in turn reduces the materials cost of the material vendor.

TABLE II
PREDICTED MONTHLY STEEL AMOUNT DURING THE OPTION PERIOD

Period(months)	Amount of steel(tons)
1	5,984
2	6,430
3	7,264
4	8,943
5	9,659
6	11,405
7	13,445
8	13,860
9	14,487
10	13,987
11	13,188
12	13,051
total	131,704

TABLE III
PARAMETERS FOR ESTIMATING OPTION VALUES

Parameters	Value
Underlying asset value(S_0)	\$586
Striking price(X_c)	\$650 ~ \$750
Volatility (σ)	8% ~ 18%
Risk free rate (rf)	4.04%
Time step (dt)	1 month

The parameters were chosen for the analysis as follows.

The underlying asset value(S_0) was set at \$586 which was the steel price per ton at the time of option contract initiation. The X_c was estimated to have maximum value of \$750 according to the calculation based on interest rate. Since the construction company could strategically lower the X_c, the analysis was conducted down to \$650which was slightly higher than S_0. For the volatility(σ) measurement, the steel material price data from December 2007 was used, given that the research starting point was January 2008. The σ was measured within a range of 8%-18% each year, using steel price data from the past. The interest rate of three-year government and public bonds was used as the risk-free rate (r_f), which was 4.04%. The time step was set at 1 month. Using these parameters, the option value was calculated, and X_p that had an identical option value was subsequently calculated.

B. Outputs of the Model

This study computed option value using a binomial lattice model. First, in the case of the call option, various option values were computed according to the X_c and σ. Next, the X_p of the put option whose value was equivalent to the call option was individually computed. Finally, the cost saving of steel material was calculated according to the change in X_c and σ. Cost saving was computed based on (8). The analysis results are summarized in Table 4.The analysis results indicate that the cost saving of the construction company increased as X_c decreased. This was because the critical level of the steel materials price increasewas set at a low level. However, as X_c decreased, $X_p$of a put option that had an identical option value gradually increased. Cost saving increased as X_c decreased. However, as X_p gradually increased, the risk of loss from a construction company increased as the steel materials price decreased. Meanwhile, cost saving did not occur for the construction company, because of volatility. This result originated in the zero-cost features of the two-way contract of the collar option. In the case of the regular one-way option, the transaction cost had to be subtracted from the cost saving. The transaction cost originated from an option value that fluctuated with the volatility. That is, the cost saving of the one-way option was affected by the volatility. Meanwhile, even though the collar option with zero transaction cost cut the connection between volatility and cost saving, there was a risk of exercising the put option.While the values summarized in Table IV are cost saving from the point of view of the construction company, it was a loss for the supplier. However, the cost savings from the materials price fluctuation did not occur only on the construction company's side.Fig. 3 below depicts the recent pattern of actual steel prices in Korea.During the research period, it was conjectured that the construction company had a cost saving, following the drastic price increase in 2008(shaded time of period as A in Fig. 3. In 2009(shaded time of period as B in Fig. 3, a rapid drop in materials price would have enabled material vendors to achieve cost savings by exercising put options. As the main body of cost saving differed with different contract timing, the supplier would have had to establish an efficient materials supply plan based on the estimated amount that was obtained from the option contract in order to reduce the risk.

$$\text{Cost saving}(\%) = \left\{ \sum_{t=1}^{12} M(t) \times (S_{no-collar}(t) - S_{collar}(t)) \right\} / \left\{ \sum_{t=1}^{12} M(t) \times S_{no-collar}(t) \right\} \quad (8)$$

$$\text{Cost saving}(\%) = 1 - \sum_{t=1}^{12} S_{collar}(t)/S_{no-collar}(t)$$

M(t) : Expected steel materials each month (Table II)
$S_{no-collar}(t)$: Monthly steel price between companies in the case of no option contra
$S_{collar}(t)$: Monthly steel price between companies in the case of an option contract

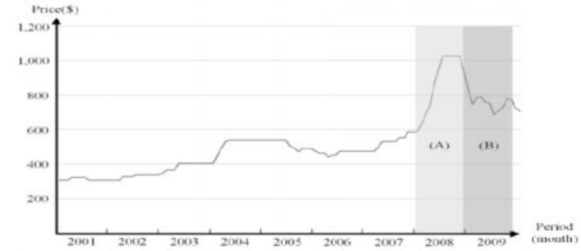

Fig. 3 Variations in steel price in Korea

VI. Conclusion

The construction industry has uncertain material requirements, due to its unique characteristics. Hence, it responds sensitively to materials price fluctuation. This paper proposed a zero-cost material procurementcontract model using a collar option to hedge risk from materials price fluctuation. It also verified the validity of its proposed model by measuring cost saving during a certain period, using steel materials as the sample.In the case of the option contract, profit and loss differs for the contract holders following the future materials price fluctuations. That is, the exercise of an option results in profit on one side and loss on the other side. Hence, it is important to prepare for any unfavorable change in the materials price in the future, when agreeing to a materials contract using an option.

TABLE IV
RESULTS

X_c ($)	Volatility												Cost saving (%)
	8%		10%		12%		14%		16%		18%		
	Option Value ($)	X_p ($)	Option Value ($)	X_p ($)	Option Value ($)	X_p ($)	Option Value ($)	X_p ($)	Option Value ($)	X_p ($)	Option Value ($)	X_p ($)	
750	0.025	488.2	0.296	493.7	1.210	496.8	2.256	496.7	4.749	499.9	7.238	500.9	20.32
745	0.030	489.2	0.337	495.0	1.385	500.9	2.543	499.6	5.230	503.2	7.688	503.8	20.75
740	0.035	490.2	0.378	496.2	1.559	504.6	3.065	503.5	5.712	506.4	8.138	506.6	21.18
735	0.072	497.0	0.525	500.5	1.734	507.9	3.586	507.3	6.193	509.7	8.588	509.4	21.61
730	0.126	506.0	0.731	506.5	1.908	510.3	4.108	511.2	6.674	513.0	9.038	512.2	22.07
725	0.180	510.7	0.937	512.3	2.083	511.7	4.630	515.0	7.156	516.1	9.488	515.0	22.53
720	0.234	512.8	1.143	517.5	2.368	514.0	5.152	518.8	7.637	519.3	10.123	518.7	23.00
715	0.289	514.9	1.349	521.3	2.944	518.7	5.674	522.5	8.119	522.4	11.245	524.8	23.46
710	0.343	516.9	1.555	523.6	3.520	523.3	6.195	526.2	8.600	525.3	12.367	529.2	23.92
705	0.397	518.9	1.761	525.4	4.096	527.9	6.717	529.7	9.082	528.1	13.489	532.6	24.39
700	0.652	527.8	1.966	527.3	4.672	532.3	7.239	533.0	10.249	533.9	14.610	536.1	24.85
695	0.911	534.1	2.335	530.7	5.248	536.6	7.761	536.1	11.429	537.8	15.732	539.5	25.31
690	1.170	537.1	2.990	536.6	5.824	540.4	8.282	538.8	12.608	541.5	16.854	542.8	25.77
685	1.428	540.0	3.644	542.1	6.400	544.0	9.362	542.9	13.788	545.2	17.976	546.2	26.24
680	1.687	542.8	4.299	547.1	6.976	546.9	10.613	547.1	14.967	548.9	19.098	549.6	26.74
675	1.946	545.5	4.953	551.4	7.553	548.9	11.865	551.2	16.147	552.6	20.220	552.9	27.23
670	2.527	551.2	5.607	554.4	8.605	552.7	13.116	555.3	17.326	556.2	21.342	556.2	27.72
665	3.306	557.4	6.262	556.9	9.950	557.3	14.368	559.3	18.506	559.8	22.463	559.5	28.22
660	4.086	561.4	6.916	559.3	11.296	561.9	15.619	563.2	19.686	563.3	23.585	562.7	28.71
655	4.865	564.7	8.018	563.5	12.641	566.3	16.871	567.1	20.865	566.8	24.707	565.9	29.20
650	5.644	568.0	9.494	568.8	13.987	570.7	18.123	570.9	22.045	570.2	25.864	569.1	29.69

While the short-term contract type is the most common among general material contracts, a long-term option contract is possible in the case of using an option according to the termination date. The advantage of such a long-term contract is that it enables contract holders to build an efficient materials supply plan because material vendors can predict the amount of materials that the construction company will use at each time point up to the contract's expiration. This increases the productivity of materials, eventually decreasing the materials cost. The material vendors can make use of such materials cost savings to prepare themselves for cases in which the materials price moves unfavorably. Meanwhile, even though a relative loss can appear on the construction company's side following the exercise of the material vendor's put option, the amount is not exactly a loss. That is, the fact that the material vendor exercises a put option means that the materials price has decreased. In other words, the construction company can obtain earnings higher than expected at the beginning of the project, due to the lower materials price.The analysis method used in this study which focused on steel materials, can be generalized for examining contracts involving other materials. Moreover, diverse contract schemes are expected to be derived according to the contract structure such as the barrier option and the composite option. The diversification of contract methods will be an efficient way to secure flexibility in responding to a variety of situations.

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