THEORETICAL ANALYSIS OF CONSTRUCTION CONTRACT FROM PERSPECTIVE OF COGNITION AND INCOMPLETE CONTRACT

Wenjun ZHANG[1], Hisanao KAJIURA[2], Masamitsu ONISHI[3], Kiyoshi KOBAYASHI[4]

[1] Student Member of JSCE, Doctor Course, Dept. of Civil Eng., University of Kyoto
(Kyotodaigaku-Katsura, Nishikyo-ku, Kyoto 615-8540, Japan)
E-mail:zhangsmile1988@gmail.com
[2]Member of JSCE, Senior Director, CBRE
(Shiba Park Building B-13F 2-4-1 Shibakoen, Minato-ku, Tokyo 105-0011 Japan)
E-mail: h.kaji01@gmail.com
[3]Member of JSCE, Associate Professor, Disaster Prevention Research Institute, University of Kyoto
(Gokasho, Uji, Kyoto, 611-0011, Japan)
E-mail: onishi.masamitsu.7e@kyoto-u.ac.jp
[4] Fellow Member of JSCE, Professor, Graduate School of Management, University of Kyoto
(Yoshida-Honmachi, Sakyo, Kyoto, 606-8501, Japan)
E-mail: kobayashi.kiyoshi.6n@kyoto-u.ac.jp

According to the characteristics of construction work, the construction contract is obviously and inevitably incomplete. Therefore, in construction field, inefficiencies caused by incomplete contract may lead to a great loss of both social welfare and social efficiency. Generally, the variation of design is normally observed during construction period and may bring wasting of resources. However, it is very difficult for contracting parties to ensure the appropriate design ex ante since people are bounded rational and investigation is also costly. This paper introduces the concept of cognition effort exerted by the contracting parties to analysis the precontractual efficiency. It finds out that under one-sided cognition situation which only the client has the ability to exert cognition effort, the social efficiency can be achieved on certain conditions. And it also shows that the contractor may have incentive to share information as well in order to maintain long-term relationship and maximize own profit.

Key Words: *construction contract, incomplete contract, design variation, cognition*

1. INTRODUCTION

Infrastructure construction is the common material foundation of social economic activity and the people's live hood. It is the guarantee of the normal operation of the main facilities of the city. The construction of infrastructure therefore has a great effect on economic and social development. However, due to the complexities of construction project, changes in the process of construction usually cannot be avoided, so it is difficult to achieve the social efficiency. Many time delays, cost overruns and quality defects of construction can be attributed to changes at various stages of a project.[1)-3)] In construction projects, a change refers to an alteration to design, building work, project program or other project aspects caused by modifications to preexisting conditions, assumptions or requirements. Construction, as a project-based practice, is particularly prone to a high degree of change for a variety of reasons.[4)-5)] Many factors can be the cause of changes in construction projects, one of the most influential factor is design change. [6)]

On the other hand, in addition, factors such as incompleteness of construction contract and bounded rationality of human beings may also lead to the inefficiency of construction projects. Problems generally arise from causes about which we are ignorant, for which we lack information, or that we cannot control [(7)]. Tirole (2009)[8)] follows the bounded rationality approach by accounting for cognitive limitations and takes rational choice approach to contracting: parties are unaware, but aware that they are unaware. He introduces the concept of cognition effort and analyzes the efficiency of sales contract under the situation of design changes.

This study follows Tirole's work and analyzes the efficiency of construction contract. Construction contract is a typical incomplete contract that cannot describe the possibility of contract variation with detail at the time of contracting. In addition, design change is regarded as one of major reasons that may lead to project inefficiency. When contracting parties can exert cognition effort and investigate the appropriate design ex ante, the negative effects brought by incompleteness of construction contract may be overcome. This research studies the precontractual efficiency in the case of construction project by introducing cognition effort and cognitive cost.

The rest of this paper is organized as follows: In order to show the basic philosophy of this study, Section 2 summarizes the theoretical background on construction contract as incomplete contract and explains cognitive effort in this research. In Section 3 to section 5, we develop the framework and build the cognition model of construction contract. Section 3 focuses on obedient player model while section 4 analyzes strategic contractor model. In section 5, we extend the analysis to two-sided cognition situation where both contracting parties can make cognitive effort. Section 6 is the discussion of conclusions. The last part section 7 summarizes the results of this study and envisages the future research directions.

2. BASIC IDEA

(1) Relationship to the literature

This paper is mainly based on the founder paper from Tirole (2009) called *cognition and incomplete contracts*. According to Halonen-Akatwijuka, M., & Hart, O. D. (2013)[9], the main insight of this paper is that: Agents are aware of their cognitive limitations, in the sense that they know that they may not be aware of the best design for the traded good. The agents can invest in finding out about alternative designs, if agents invest little, contracts are incomplete and there is a high probability that the contract has to be renegotiated. However, contracts may also be too complete if too many resources are spent on search to avoid a vulnerable position in renegotiation. The originality of the paper is that it introduces the concept of cognition which makes the incompleteness of incomplete contract become endogenous. Since the conceptual work such as thinking about contingencies is no longer costless, in addition, according to bounded rationality approach, there exists cognitive limitation among human beings. On the other hand, according to rational choice approach, people tend to adopt the best strategy to minimize the cost to obtain the maximum benefit which can be described as objective optimization or utility maximization. Tirole combines the mainstream contract theory and bounded rationality approach, proposes that parties are unaware, but aware that they are unaware which means that human beings have cognition limitations, and they know the existence of their cognition limitations as well. Since his paper mainly applies for the condition of sales contract, it assumes that the buyer first takes delivery and possession of the good and then discovers whether the design is appropriate or not. Finally, he indicates that under the condition of sales contract, there exists a cut-off value of the seller's bargaining power which is the boundary of negotiation break down and excessive completeness. Ex ante competition need not reduce transaction costs. And contracts are predicted to be strictly less complete under relational contracting or under vertical integration. Furthermore, long-term contracting may be strictly suboptimal.

In addition to Tirole's paper, Shi (2010)[10] theoretically investigates the optimal procurement contract between the owners in developing countries through double moral hazard issue. Omoto (2001)[11] makes comparative study between the GCW forms and the FIDIC forms, claims that clear differences in both contract forms in coping with endogenous risks can be found, while there are no essential differences in resolving exogenous ones. Kobayashi (2001)[12] provides theoretical explanation of efficiency and the social optimal form of Japanese construction contract, but assumes that parties continue the transaction according to the content of initial contract when renegotiation breaks down.

However, those literatures have not taken the consideration of cognition and the precontractual efficiency into consideration. No such study has been found in construction field. This paper takes cognition effort into account and analyses the efficiency of construction contract under the situation of design alteration.

(2) Variation rule in FIDIC contract

Since construction contract is a typical incomplete contract, it is impossible to record all of situations that may occur in the future in advance. Therefore, when the construction contract needs to be modified, it is necessary to establish the rules to determine the content of variation. This is called contract variation rule. The design of contract variation rule should consider the strategic choices made by contracting parties through contract variation, in order to reduce or avoid the transaction cost caused by moral hazard and hold-up problem.

The contract variation rule in FIDIC[13] form is shown in Figure-1. The procedure starts from the time-point when the contractor became aware, or should have become aware of the event or circumstance. According to the Article 20.1 of FIDIC form,

the contractor shall give notice to the engineer within 28 days after the awareness of the event. The notice should describe the event or circumstance giving rise to the claim. And within 42 days after the awareness, the contractor is required to submit a fully detailed claim report to the engineer. Within 42 days after receiving the claim report, the engineer shall respond with approval, or with disapproval and detailed comments. If both employer and contractor agree with engineer's decision, contract can be modified with this content. If either or both parties disagree with the decision, then it will proceed to the dispute settlement. However, taking into account that the engineer is employed by the employer, the decision of the engineer, to a large extent, reflects the intention of the employer. Therefore, the party who often opposes engineer's decision is generally the contractor.

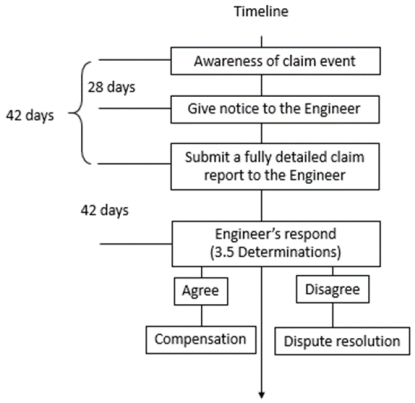

Figure-1 Contract variation rule in FIDIC contract

In the case of design change, when adjustment cost of design changing occurs, the contractor is entitled to claim for the compensation to the client through engineer. The engineer will respond to his claim requirement. If the parties cannot reach an agreement on the amount of compensation, then they will proceed to dispute resolution.

(3) Incomplete contract and cognitive effort

There is a wide range of risks existing in construction projects. It includes natural factors such as geological conditions and weather as well as socio-economic factors such as material and labor costs and so on. However, even if risk factors can be specified, it is impossible for the contract to describe all matters that may occur in the future. Such contract which cannot specifically describe all the contingencies that may arise in the future is called incomplete contract. [14),15),16)] Omoto, etc[11)] have pointed out that the construction contract is a typical incomplete contract[14)15)16)].In incomplete contract, when contingency has occurred, after observing the generated result, contracting parties have no choice but revise the contract content by renegotiation.

Incomplete contract theory has been gradually developed according to the theory of Grossman and Hart[17)] and has also accumulated findings of desirable contract and institutional design on the premise of incomplete contract. Based on the incomplete contract theory, when the contingency occurs, contracting parties have to determine the terms of the agreement by renegotiation. In the process of renegotiation, the parties may change his position by making use of information asymmetry to review the allocation of project surplus decided in the initial contract. When the parties believe that it is likely to modify the initial contract by renegotiation, in order to ensure the bargaining power of renegotiation, they will try to suppress the investment in the early stages of the project. Therefore, there is a risk to adopt opportunistic behavior. Such underinvestment is known as the hold-up problem. Therefore, in incomplete contract, contract variation rules which can inhibit hold-up problem are indispensable.

Variation almost always exists in the construction work process, and it inevitably can have a significant impact on labor productivity.[18)] A significant amount of research has been performed in reference to factors affecting construction productivity and many scholars have pointed out that design change is one of the major factors affecting productivity of construction project.[19)20)21)22)23)] Design change may give raise to construction waste[24)],delay, cost overruns and even termination of contract. Design change refers to any change in the design or construction of a project after the contract is awarded and signed. Such changes are related not only to matters in accordance with the provision of the contract but also changes to the work conditions[25)].Similarly, Akinsola et al. (1997)[26)] noted that these changes are any additions, omissions or adjustments made to the original scope of work after a contract is awarded. It may cause an adjustment to the contract price or contract time, and it occurs regularly on construction projects[27)]. Likewise, Park (2003)[28)] defined that construction changes refer to work state, processes or methods that differ from the original construction plan or specification and usually resulted from different in work quality and conditions, scope changes or uncertainties that make construction dynamic and unstable.

On the other hand, Cognition is the mental action or process of acquiring knowledge and understanding through though, experience, and the senses. Cognitive effort in this paper refers to the ability that contracting parties can realize or investigate the inappropriateness of initial design using heuristics. The contracting parties may initially contract on an

available design which may be the best one under their existing knowledge. After a period of time, either or both of contracting parties may realize that the initial design may not be appropriate and should be modified. When ex post design change becomes inevitable, along with the reduction of social welfare and construction efficiency, there also exists a kind of regret. If contracting parties are able to exert a massive effort, it may be more likely for them to find the appropriate design before contracting or the time that may cause losses. When the appropriate design can be contracted ex ante, the design change ex post can be avoided, or the higher the appropriateness of initial design is, the lower the cost of ex post design change will be. Therefore, the inefficiency caused by design change could be improved by guaranteeing precontractual efficiency. However, excessive investment of cognition effort may also lead to excessive completeness of the contract which may result in the waste of resources.

In total, design change is one of major causes of project inefficiency while moderate cognitive effort may mitigate this negative impact.

(4) Feature of construction contract

Construction contract is a legal binding agreement signed by contracting parties that the contractor undertakes the construction and maintenance work according to the client's requirement with labors, materials and equipment. It is a kind of promise that the contractor completes project construction, where the employer pays the price.[29] Construction work is generally large in scale and complicated. In addition, the number of contract documents is enormous which makes it impossible or prohibitively costly to consistent with all the contents such as drawings, specifications, contract terms, etc. Moreover, construction work includes various uncertain factors such as change of scope and design, revision or abolition of law, geological conditions, natural conditions, etc. These are unforeseeable risks to the contracting parties and it is impossible to control all of them.[30] In addition, as competition intensified due to a decrease in construction investment, the client become more aggressive, the construction industry is definitely a buyer's market, the status of the client is unilaterally superior to that of the contractor.[31] Moreover, because of the specific investment made by contracting parties, either of them can easily pull out of the transaction.

In the construction contract, the contractor is obliged to fulfill the contract under any circumstances. The contractor is under an obligation to complete the construction, so construction contract does not allow cancellation offered by the contractor.[11] Therefore, under the circumstances described above, there exists unilaterality between contracting parties.

However, the model described in Tirole's paper is mainly applied to sales contract. The setting in his paper describes a pure transaction sale which is based on principle of "cash on delivery". This is different from the construction contract. One is timing of cognition of appropriate design, it usually happens after the buyer took possession of the good in sales contract while in construction project, the client may realize it during the construction process. The other one is transformation of the ownership of the property and the payment. Under the situation of sales contract, it is common for contracting parties to delivery on payment and close the deal while for construction contract, payment may not be finished when completion of construction. In other words, the main different between sales contract and construction contract is that at the timing of appropriate design realization, the client may have not paid in full since transaction is not over which unlike sales contract, thus the bargaining power between contracting parties under such condition may be contrary to the condition of sales contract.

In addition, in construction contract, since the contractor has no right to cancel the contract and has to follow the client's instructions to complete construction work on time. According to the features of construction project described above, the reversal of bargaining power between client and contractor in the pre-contract and post-contrast stages is common phenomenon in construction field. Bargaining power reversal originates from the sunk cost of an investment specific to a transaction. For many practitioners who have worked on the client side, it is not an unusual observation that change of mind after the signing of contracts may cost the client dearly.[32] This is also the key distinction from the sales contract model described by Tirole (2009), since adjustment of initial design in his model always occurs after the termination of the initial contract. In other words, renegotiation of the adjustment of inappropriate design will lead to a new contract for a new transaction. Therefore, the bargaining power of contracting parties are the same once the buyer takes possession of good and pays for the production. However, in construction project, all of construction work should be completed under one contract which means that the adjustment of the initial design is also a part of initial contract. Therefore, such client-led change orders cannot be entirely avoided. When they happen, the pricing of additional work may need to be determined through negotiation if it cannot be sorted in accordance with an agreed schedule of rates. How price negotiation will wind up largely depends on bargaining power.[33]

According to Chang and Ive (2007), the reasons of

bargaining power reversal can be summarized as the following aspects:

Due to the fierce competition in construction market, the balance of bargaining power at this point can be said to lie with the client. However, after the signature of contract, the situation for both contracting parties changes to one of a degree of bilateral dependence. Moreover, the peculiar dependence of the value of a set of construction activities comprising a project on the completion of that set; the fact that the project comprises a process of building upon a fixed site, belonging to the client; and the fact that the client pays for work in process of construction, and does not only pay for a completed product. In combination, these features give the client a persistently weak bargaining position throughout post-contract stages.

3. OBEDIENT PLAYER MODEL

In this part, we tried to analyze the situation of one-sided cognition. In construction market, in order to manage an efficiency project, the responsibility of the client plays a decisive role. Although the client is a social welfare maximizer, he is motivated to exert cognition effort ex ante to find out the appropriate design in order to maximize his own profit. Therefore, will analysis the condition that only the client has the ability to learn about the appropriate design in the first step.

(1) Settings

Let us describe the model first.

Designs.— a client (B) and a contractor (S) contract on a construction project through open tender. The client first exerts cognition effort and incurs cognitive cost to investigate design A and then the contracting parties negotiate to reach a decision on the specification, contracting price and etc. The construction work of initial design A costs the contractor c to accomplish. According to peculiarity of construction contract that the contractor is prohibited from proposing contract termination except special circumstances stipulated in the contract. In addition, since the investment amount of construction project is enormous, and both contracting parties have to make relational specific investment which different from other kinds of projects. Therefore, we assume that after signature of the contract, neither side can easily withdraw from the transaction.

With the probability $1-\rho$, the initial design A is the appropriate design and delivers utility v to the client which is larger than the cost c. With the probability ρ, the appropriate design is A' and delivers utility v to the client while the design A can only deliver $v-\Delta$, where $0<\Delta<v$. If the client finds out the appropriate design A' during the process of construction, then he can apply for A' to the contractor. If the conversion is feasible, it takes the contractor cost α of this conversion, we call this cost α adjustment cost. Adjustment cost α should be smaller than Δ which is $\alpha \in [0,\Delta)$. If the adjustment cost is larger than the increment of utility between the two designs, it is meaningless to do the conversion. By contrast, if the contracting parties contract on appropriate design A' initially, then the total cost of the construction project is c and delivers utility v to the client. There is no adjustment cost.

Such adjustment cost can be interpreted in the construction field in the following ways. First, the labor force of the contractor. When the conversion takes the place, there are addition works for build labors, so not only the labor cost, but also utility expenses such as water and electricity. Second, additional building materials may be needed for conversion work, so the contractor has to arrange procurement and logistics as well as correlative charges. Furthermore, in most of the construction contract, variation of design needs to go through a set of complicated process. In addition, the contractor has to learn about the new design. Therefore, adjustment cost α can also indicate such time cost.

Design change may lead to contract variation, so the contractor is entitled to claim for extra cost or extension of time. When the contractor agrees to cooperate and adjust the design, he may submit calculated adjustment price to the engineer and claim for compensation. Then, the engineer will decide whether or not this price is reasonable. If the engineer gives the permission, the contractor will receive adjustment cost α and complete the work. If the price is considered to be unreasonable, the contracting parties have to renegotiate about it. If a final agreement cannot be achieved, they will proceed to dispute resolution.

Contract renegotiation.— If the client has learned about the appropriate design A' and specifies the construction of it, the contracting parties negotiate on the specifications and set the contracting price at p_0. Then the contractor incurs the cost c to accomplish the construction and there is no renegotiation.

By contrast, when the client has not learned the appropriate design initially and the contracting parties contract on design A. They first set the contracting price at p_0 and the contractor incurs the cost to build. However, during the construction period, if the clients realizes that A is not the ideal design, the appropriate one should be A', he will renegotiate with the contractor in order to obtain the adjustment to A'.

If the client didn't finds out the $A'$to the last, then there is no renegotiation either. The contracting parties follow the initial design and contract content until completion of the transaction.

In the model, we will assume that the client has the bargaining power of β and the client has the bargaining power of σ, where $\beta + \sigma = 1$. The bargaining power in this model measures the share of the gains that the party can secure in the renegotiation. Here, it needs to be emphasized that bargaining power of contracting parties in ex ante stage and ex post stage cannot be guaranteed to be the same because of the existence of bargaining power reversal.

The timeline of our model is showing as Figure-2.

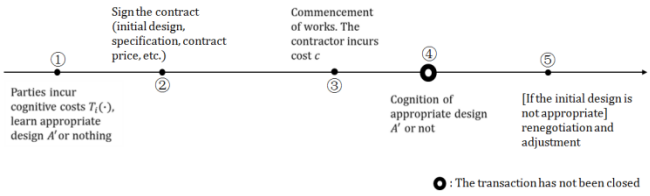

Figure-2. Timeline

In the first place, both contracting parties can exert cognition effort to investigate the appropriate design and incur cognitive costs $T_B(b)$ for the client and $T_S(s)$ for the contractor (in one-sided cognition model, only the client has the ability to exert cognition effort on the first step). The functions T_i (for $\in \{B, S\}$) are smooth, increasing, and convex functions such that $T_i(0) = 0, T_i'(0) = 0$, and $T_i(1) = \infty$. b and s denotes the level of their cognition effort respectively. If A is the appropriate design, they learn nothing from their investigation. By contrast, if A' is the appropriate one, then they learn A' with probability b and s; and they learn nothing with probability $1 - b$ and $1 - s$. After that, they negotiate to reach an agreement on the issues such as contracting price and sign the contract on the initial design. Next step is commencement of works that the contractor incurs cost c for construction. In the course of construction, the client may or may not realized the appropriate design A'. When he finds out A', then he renegotiate with the contractor. If they are successfully renegotiated, they decide a new contracting price $p^*$and recontract. Since construction work requires lots of manpower, material and financial resources. And it also involves high technology with long construction cycle. Once the construction work has been accomplished, great changes of design become impossible since it is prohibitively expensive. Therefore, in this paper, we assume that the client can find out A' during construction period if possible.

(2) First best

When only the client can exert cognition effort and incur cognitive cost $T_B(b)$, the social efficient level of cognitive cost only concerns with $T_B(b)$ and adjustment cost α, which is:

$$\min_b [\rho(1-b)\alpha + T_B(b)] \tag{1}$$

The social efficient level of cognition $\hat{b}$ is:

$$T_B'(\hat{b}) = \rho\alpha \tag{2}$$

(3) Obedient contractor model

At the beginning, we describe a model of the obedient contractor condition. We assume that there is mutual trust between the contracting parties. This means that they both believe each other's ability and judgment. And they also believe that the other party will not take strategic behavior. Information is symmetrical between the two parties.

Obedient contractor in this research refers to the contractor who takes no strategic behavior and being honest during the contract variation process. The contractor in this model will obediently follow the instructions stipulated in the contract and claim for reasonable adjustment cost. In addition, the contractor is willing to cooperate with the client for design changing, therefore renegotiation is nonexistent. Accordingly, bargaining power between the contracting parties are the same as it was in the ex ante which are $\beta = 1, \sigma = 0$.

Similarly, as the contractor, the client also follows the contract variation procedure and pays the exact amount as claimed by the contractor. Therefore, dispute resolution will not be proceeding.

Consequently, when the client proposes design change, the contractor will undoubtedly accept and offer his collaboration. After that, the contractor claim for the exact adjustment cost α to the engineer. The engineer accepts α and the client pays for compensation. The total cost for construction work to the contractor is $c + \alpha$.

The profit for the client when design change occurs is:

$$v - \alpha - c - T_B(b) \tag{3}$$

(4) Cognitive effort by the client

First, under specified situation, if the client finds out that design A' is appropriate, he will rationally disclose it and specify the delivery of design A'. Because the ex ante price always equals to the cost in competitive marketing environment, moreover, renegotiation is nonexistent under obedient contractor model, if the client conceal design A', he will wastefully lost adjustment cost α.

When the client trades even having learned nothing, his profit solves

$$\max_b[\rho b(v-c)+(1-\rho)(v-c)+ \rho(1-b)(v-\alpha-c)-T_B(b)] \quad (4)$$

Differentiating the equation yields first-order condition which is the same as the social efficient level:

$$T_B^*(\hat{b})=\rho\alpha \quad (5)$$

Proposition 1:

Under situation of obedient contractor, even if the client pursues the personal interest maximization, the social efficient can always be achieved when only the client has the ability to exert cognitive effort.

4. STRATEGIC CONTRACTOR MODEL

In this section, we analyze the situation that the contractor may act strategically during negotiation process and take advantage of his bargain power to try to obtain benefit. We call it strategic contractor model.

(1) Renegotiation for variation

When there is requirement of conversion to A', renegotiation will arise between contracting parties. Since the existence of design A' is symmetric information between the client and the contractor, we apply the generalized Nash bargaining solution with weights β and σ. Because the transaction has not been closed at the time of renegotiation, we take consequences of contract termination as status quo in this paper.

If the contractor refuses to vary the design, then the renegotiation breaks down. Since the contracting parties are still in the contractual relationship and the construction has not been accomplished, furthermore, as mentioned above, in practice, when the deal is still on, the client will not make the payment of contracting price. For those reasons, when the contractor refuses to cooperate, he cannot get paid. In other words, cost recovery cannot be achieved under such condition. The contractor's gain from initial contract is $-c$. For the client, since the construction has not been finished, it is unable to achieve its expected function. Therefore, such uncompleted construction work has no value for the client, so he can only obtain $-T_B(b)$ which is the cognitive cost he spent ex ante. By contrast, if the contractor intends to cooperate and can reach an agreement with the client, gains from the cooperation should be:

$$v-\alpha-c-T_B(b). \quad (6)$$

When the contractor converse the design, value of the construction turns to be v while the expense of adjustment cost α must be occurred. Then, the surplus of cooperation is:

$$v-\alpha-c-T_B(b)—[-T_B(b)]-(-c) = v-\alpha. \quad (7)$$

Because when renegotiation breaks down, both the client and the contractor suffer losses, therefore, they may try to cooperate and theoretically neither of them can obtain full bargaining power. Nevertheless, they renegotiate about the distribution of cooperation surplus. Regarding redistribution, both are in a conflict situation. Therefore, the contracting parties may capture a fraction of the cooperation surplus with weights β and σ. The client may obtain:

$$\beta(v-\alpha), \quad (8)$$

and the contractor may obtain:

$$\sigma(v-\alpha). \quad (9)$$

The total benefit that the contractor can earn from the trade when renegotiation occurs is thus:

$$\sigma(v-\alpha)-c. \quad (10)$$

In practice, the construction project bidding is usually in the form of open tendering. In addition, in the construction market, competition among the contractors is fierce, therefore, the ex ante contracting price of the initial price should be competitive price which is:

$$p_0=c \quad (11)$$

Then, when conversion is required and parties reach an agreement through renegotiation, since the client won't pay more than the least amount that the contractor can earn, the new contracting price is:

$$p^*=\sigma(v-\alpha) \quad (12)$$

In addition, the contractor's bargaining power σ should not be zero here. If the contractor has no bargaining power, then his ex post utility is $-c$. Since the contractor may predict the occurrence of such situation, he will not contract with the client at the beginning, in other words, the contract will not be established. Thus $0<\sigma<1$. The contractor's hold up benefit is denoted with h, where $h=\sigma(v-a)-c$.

Moreover, let $\hat{\rho}(b)$ denotes the posterior probability that A is not appropriate conditional on cognitive intensity b and unawareness

$$\hat{\rho}(b)\equiv\frac{(1-b)\rho}{1-\rho b}. \quad (13)$$

On the equilibrium path where $b=b^*$. Since the design change occurs during the contract period, the initial price for the construction project can be rewritten as:

$$p(b^*)=c+\hat{\rho}(b^*)[\sigma(v-\alpha)-c] \quad (14)$$

Proposition 2:

When requirement of design change leads to renegotiation, the contractor may capture an amount of hold-up benefit $\sigma(v-\alpha)-c$ which is not less than that of initial contract. Since the client will not pay more than the least amount that the contractor can earn, the new contracting price is $p^*=\sigma(v-\alpha)$.

When design change occurs, due to the consequence of renegotiation breakdown, the bargaining power of either party would not be zero. Therefore, the contractor may always get an amount of benefit through renegotiation.

(2) Incentive for disclosure

Suppose that the client finds out that A' is appropriate, by concealing design A', his gets:

$$v-\alpha-p(b) \tag{15}$$

By disclosing A', the client's profit is:

$$v-p_0=v-c. \tag{16}$$

Thus, disclosing A' increases the client's utility by

$$\Delta U_B=v-c-[v-\alpha-p(b)], \tag{17}$$

or

$$\Delta U_B=\hat{\rho}(b)[\sigma(v-\alpha)-c]+\alpha.$$

This is nothing but adjustment cost and the contractor's utility gained from renegotiation. Since equation $\sigma(v-\alpha)-c$ refers to the total benefit that the contractor can earn through renegotiation, it should not be less than 0. In addition, adjustment cost $\alpha\in[0,\Delta)$, therefore $\Delta U_B\geq 0$. Therefore, the client will definitely propose to contract on design A' when he becomes aware or he has to pay at least the adjustment cost of conversing to appropriate design.

As a consequence, the client will always disclose the appropriate design when he becomes aware of it.

Proposition 3:

The client always has the incentive to disclose the appropriate design when he becomes realize of it, since the benefit he can get from the appropriate design is at least as large as that of design A'.

(3) Cognitive effort by the client

Consider the situation that the client trades even when having learned nothing, his utility solves

$$-T_B(b)+\rho b(v-c)+(1-\rho b)\{[1-\hat{\rho}(b)](v-c)+\hat{\rho}(b)[v-\alpha-c-(p^*-c)]\} \tag{18}$$

With the probability ρb, the client awares the appropriate design A' ex ante and his utility is $v-c$.

With probability $1-\rho b$, the contracting parties contract on design A with price $p_0=c$.

With probability $1-\rho$, A is the appropriate design and the client can also obtain $v-c$. With probability $\rho(1-b)$, the appropriate design is A' but the client fails to find out it ex ante, therefore, the contracting parties contract on design A first and then renegotiate. Since the client in practice does not always act as a social welfare maximizer, he goes after individual profit as well.

Therefore,

$$\max_b\{-T_B(b)+\rho b(v-c)+(1-\rho b)\{[1-\hat{\rho}(b)](v-c)+\hat{\rho}(b)[v-\alpha-c-(p^*-c)]\}\} \tag{19}$$

Differentiating the above equation yields first-order condition:

$$T_B'(b^*)=\rho\hat{\rho}(b^*)[\alpha+\sigma(v-\alpha)-c] \tag{20}$$
$$=\rho\alpha+[\hat{\rho}(b^*)h-(1-\hat{\rho}(b^*))\alpha]$$

The left-hand side of this equation is the client's marginal cost of cognition. His marginal benefit which is the right-hand side is composed of three terms. The first one is the social benefit $\rho\alpha$. The second term can be interpreted as a hold-up discount and the third term refers to the adjustment cost which can be avoided under the condition of ex ante unawareness.

Using the Bayesian updating condition, $\hat{\rho}(b)=\rho(1-b)/(1-\rho b)$, equation (20) can be written as:

$$T_B'(b^*)=\frac{\rho(1-b^*)h-(1-\rho)\alpha}{1-\rho b^*}+\rho\alpha \tag{21}$$

ASSUMPTION 1:

$$T_B''(b)>\frac{\rho^2(\rho-1)}{(1-\rho b)^2}[\sigma(v-\alpha)-c+\alpha] for\ all\ b\in[0,1]$$

Assumption 1 ensures that the condition (21) has a unique solution, which lies in (0, 1). In other words, it guarantees uniqueness of the deterministic cognition equilibrium.

Condition (21) implies that the equilibrium transaction cost of cognition effort by the client b^* increases with adjustment cost α and is largely affected by the contractor's bargaining power.

In order to check whether or not the employer's marginal cost of cognition is larger than social efficiency, we have to ensure the sign of the first term of the formula above, therefore

Since $1-\rho b\geq 0$, the sign is determined by $\rho(1-b)h-(1-\rho)\alpha$:

When

$$\frac{h}{\alpha} \geq \frac{1-\rho}{\rho(1-b)}$$

Which is that when ratio of hold-up amount by the contractor to the amount of adjustment cost becomes larger than the ratio of probability that A is appropriate design to the probability that A' is the appropriate one but remain unaware, the employer's marginal cost of cognition will exceed social efficiency level.

Since $h = \sigma(v-a) - c$, from the formula above, it is obvious that whether or not the employer's marginal cost of cognition is larger than social efficiency mainly depend on the value of hold-up amount, which is determined by the contractor's bargaining power and the adjustment cost.

As the consequence, the equilibrium value of the client's cognitive intensity is mainly affected by the adjustment cost α and the contractor's bargaining power. When the contractor's bargaining power increases, the value of hold-up will also increase correspondingly which may result in high probability of the excess of social efficiency where the contract is too complete. On the other hand, increased adjustment cost will inversely lead to insufficient cognition effort. Moreover, when the client intends to exert redundant cognitive effort to avoid the inappropriateness of initial design and the contractor's hold-up, the cognition intensity b may increases. It may also likely lead to insufficient cognition.

Precondition of the unique solution.

In order to check whether or not the cognitive effort b^* is indeed the equilibrium, it is necessary to check that the client will conclude the contract only when he becomes aware. Therefore, when the client planning not to write a contract when unaware, let us assume that his optimal cognitive effort is b'.

$$b' = argmax_{\{b\}}\{-T_B(b) + \rho b(v-c)\}$$

A necessary and sufficient condition for b^* to be the equilibrium cognitive strategy is thus

$$v - c - \rho(1-b^*)(\alpha + h) - T_B(b^*) \geq \rho b'(v-c) - T_B(b')$$

First, when $\beta = 0, \sigma = 1$, and for any α, It is always better for the client to trade even under the condition of unawareness:

$$\max_b[(1-\rho)(v-c) + \rho b(v-c) - T_B(b)] \geq \max_b[\rho b(v-c) - T_B(b)]$$

Conversely, when the employer's bargaining power $\beta = 1$ and the contractor's bargaining power $\sigma = 0$, the case should be

$$U^{NT}(b) = \max_b\{\rho b(v-c) - T_B(b)\}$$

and

$$U^T(b) = \max_b\{v - c - \rho(1-b)(\alpha - c) - T_B(b)\} = \max_b\{\rho b(v-c) + (1-\rho b)(v-c) - \rho(1-b)(\alpha-c) - T_B(b)\}$$

Since $(1-\rho b)(v-c) \geq \rho(1-b)(\alpha-c)$, therefore

$$\max_b\{v - c - \rho(1-b)(\alpha-c) - T_B(b)\} \geq \max_b\{\rho b(v-c) - T_B(b)\}$$

The inequation above refers that even if in the extreme case that the client has no bargaining power while the contractor has a strong voice, trade remaining unaware is always the optimal choice for the client.

Consequently, unlike the existence of a unique cut-off value of the seller's bargaining power in sales contract, since it is always beneficial for the client to trade even if he is unaware, the cognitive intensity b^* is indeed equilibrium. Such case can also be found during the practice, due to the characteristics of construction project such as long life cycle, complicated construction condition or large up front investment, it is extremely difficult for the client to aware the appropriate design initially, therefore, trade even if remaining unawareness is common case in construction field.

Proposition 4:

Under one-sided cognition case, the transaction cost increases with the contractors bargaining power and affected by adjustment cost, therefore, social efficient level of cognitive effort can be achieved by the client when meet some conditions theoretically.

5. TWO-SIDED COGNITION MODEL OF CONSTRUCTION CONTRACT

(1) The contractor's incentive of exerting cognition effort

This section discusses the contractor's incentive of exerting cognition effort. Suppose that the contractor becomes aware that design A' is the appropriate one. The contractor obtains

$$p_0 - c = c - c = 0$$

by revealing it. By concealingA', he obtains, instead,

$$p(b^*) - c = \hat{\rho}(b^*)[\sigma(v-\alpha) - c].$$

Therefore, the effect on the contractor ΔU_s is:

$$\Delta U_s = \hat{\rho}(b^*)[\sigma(v-\alpha)-c].$$

When $\Delta U_S \leq 0$, since $\hat{\rho}(b^*)$ is never less than 0, therefore it must be the case that

$$\sigma(v-\alpha)-c<0.$$

Consequently, when $\Delta U_s > 0$, the contractor prefers to contract on design A ex ante, since he can earn an extra benefit. When $\Delta U_s \leq 0$, the contractor prefers to contract on appropriate design A' at ex ante stage, because the adjustment and renegotiation will make him suffer a great loss. However, under such condition, the ex ante may probably break down, because the contractor may probably predict this situation. The new contracting price must be at least as large as the construction cost.

Therefore, since ΔU_S is always larger than 0, the contractor is certain to earn through renegotiation, if fixing α, the value of ΔU_s is largely dependent on the contractor's bargaining power σ. In construction field, even if bargaining power reversal exists, it is common that the client has the initiative in his hands. Therefore, the contractor's bargaining power is generally marginalized. On the other hand, since design alteration is common in construction field, in order to earn benefit from renegotiation, the adjustment cost should be as little as possible. The most direct way to minimize the adjustment cost is to find out the appropriate design as earlier as they can. Consequently, in the early days, both contracting parties have incentives to investigate for design A'. In addition to this, the desire of long-term relationship establishment with the client may also be the incentive for the contract to disclose appropriate design ex ante.

6. DISCUSSION

In this research, it is found that marginal cognition cost of the client is determined by bargaining power of contracting parties and the amount of adjustment cost. It is possible for the client's marginal cost of cognition to achieve social efficient level theoretically. When the contractor's bargaining power increases, the value of hold-up will also increase correspondingly which may result in high probability of the excess of social efficiency where the contract is too complete. On the other hand, increased adjustment cost will inversely lead to insufficient cognition effort. In addition, it is always optimal for the client to trade even remaining the unawareness of appropriate design which is indeed the case in practice. Because when adjustment cost is less than value of construction project, bargaining power of contracting parties has no affect on the client's gain. Finally, when the contractor's bargaining power is inferior to a certain degree, he is motivated to share information of the appropriate design during construction process in order to obtain more hold-up.

Due to the particularity of the construction project, renegotiation caused by adjustment of inappropriate initial design occurs during the transaction. Moreover, large amount of specific investment required in early stage of construction project and the prohibitive provisions of contract termination in construction contract lead to transformation of bargaining power which gives the contractor a relatively strong bargaining position throughout post-contract stages. Besides the differences of timeline between sales contract and construction contract, inconformity of contracting parties' bargaining power ex ante and ex post is another main cause of different conclusions between two kinds of contracts.

In this research, ex post renegotiation is considered to be resulted from inappropriate initial design which is determined by the cognition effort exerted by the client. However, initial cognition effort is not costless, transaction cost occurs when the client trying to find out an appropriate design ex ante. During renegotiation, due to reversal bargaining power between contracting parties, the client is probably being held-up by the contractor. On the other hand, the amount of contractor's hold-up is affected by his bargaining power and adjustment cost. When adjustment cost is fixed, if contractor has very strong bargaining power ex post, the client's marginal cognition cost will exceed the social efficient level in order to maximize his profit. But relatively, when the contractor's bargaining power is less than the cut-off value, a bargaining breakdown may occur at the ex ante stage since he may suffer a loss because of renegotiation. Neither of the condition will motivate the contractor to disclose appropriate design at ex ante stage. Nevertheless, when contractor has a certain bargaining power which makes it no different for him before or after renegotiation, in domestic construction market where repeated transaction is usual, the contractor is likely to disclose the appropriate design ex ante because of establishment and maintaining of a good long term cooperate relationship. However in international construction market, since one-shot type relationship is commonplace, there is no motivation for the contractor to disclose.

On the other hand, unlike sales contract, construction work is an integral and continuous process, the time point of awareness of appropriate design has a nonnegligible affect on the amount of adjustment

cost. When contracting party is aware of appropriate design at the early stage after the contract signature, there is no need to make large scale changes which may reduce adjustment cost since construction work is still at the starting stage. In practice, since the contractors are the main body of construction work, it may be liable for them to find design problem than the client. When contractor's bargaining power is mainly determined by the client or some external factors, incentives of sharing information on appropriate design may generate from adjustment cost. Especially in domestic market, while increasing own interests, ex post sharing information is also very positive for establishment of long-term cooperation relationship.

7. CONCLUSION

This research follows Tirole's work and analyzes the trade-off solution of cognition effort exerted by the client under the condition of construction project. Due to the main difference between sales contract and construction contract, it is found that the amount of adjustment cost and bargaining power after renegotiation between contracting parties are main influencing factors of the equilibrium of cognition intensity. In addition, unlike sales contract, the timing of ex post cognition of appropriate design is one of main motivations of information sharing by the contractor.

However, this research just indicates the equilibrium solution under the situation of one-sided cognition. In next research, we will take two-sided cognition where the contractor also has the ability to exert cognition effort into consideration. In addition, other conditions for example when appropriate design being cognized initially is not the most appropriate one, whether or not the solution in this paper is applicable is still undefined. This is also a topic for future challenge.

ACKNOWLEDGMENT:

REFERENCES

1) Burati JL, Farrington JJ, Ledbetter WB. Causes of quality deviation in design and construction. J Constr Eng Manage 1992;118(1):34.49.

2) Love PED, Mandal P, Li H. Determining the causal structure of rework influences in construction. Constr Manage Econ 1999;17(4):505.17.

3) Love PED, Li H. Quantifying the causes and costs of rework in construction. Constr Manage Econ 2000;18(4):479.90.

4) Hsieh T, Lu S, Wu C. Statistical analysis of causes for change orders in metropolitan public works. Int J Project Manage 2004;22(8):679–86.

5) Wu C, Hsieh T, Cheng W. Statistical analysis of causes for design change in highway construction on Taiwan. Int J Project Manage 2005;23(7):554–63.

6) Analysis of factors affecting design changes in construction project with Partial Least Square (PLS) (A. A. Gde Agung Yanaa,*, Rusdhi H. A.b, M. Agung Wibowoc, 2015)

7) Ross, Timothy J. *Fuzzy logic with engineering applications*. John Wiley & Sons, 2009.

8) Tirole, Jean. "Cognition and incomplete contracts." *The American Economic Review* 99.1 (2009): 265-294.

9) Halonen-Akatwijuka, Maija, and Oliver D. Hart. *More is less: why parties may deliberately write incomplete contracts*. No. w19001. National Bureau of Economic Research, 2013.

10) 石磊, 宮尾泰助, and 小林潔司. "建設契約におけるダブルモラルハザード." *土木学会論文集 D* 66.4 (2010): 414-430.

11) 大本俊彦, 小林潔司, and 若公崇敏. "建設請負契約におけるリスク分担." *土木学会論文集* 693 (2001): 205-217.

12) 小林潔司, et al. "建設請負契約の構造と社会的効率性." *土木学会論文集* 688 (2001): 89-100.

13) Federation Internationale Des Ingeniers Conseils (FIDIC): Conditions of Contract for Construction, 1st Edition, 1999.

14) Williamson, O. E.: *Marketsand Hierarchies: Analysis and Antitrust Implication*, The Free Press, 1975.

15) Williamson, O. E.: Economic Institutions of Capitalism, Firms, Markets, Relational Contracting, The Free Press, 1985.

16) Klein, B., Crawford, R. and Alchian, A.: Vertical integra-tion appropriable rents and the competitive ontracting process, Journal of Law and Economics, Vol. 21, pp. 297－326, 1978.

17) Grossman, S. J. and Hart, O. D.: The costs and benefits of ownership: A theory of vertical and lateral integration. Journal of Political Economy, Vol. 94, No. 4, pp. 691-719, 1986.

18) Wambeke, Brad W., Simon M. Hsiang, and Min Liu. "Causes of variation in construction project task starting times and duration." *Journal of Construction Engineering and Management* 137.9 (2011): 663-677.

19) Thomas, H. R., and Yiakoumis, I. (1987). "Factor model of construction productivity." J. Constr. Eng. Manage., 113(4), 623–639.

20) Herbsman, Z., and Ellis, R. (1990). "Research of factors influencing construction productivity." Constr. Manage. Econ., 8, 49–61.

21) Portas, J., and AbouRizk, S. (1997). "Neural network model for estimating construction productivity." J. Constr. Eng. Manage., 123(4), 399–410.

22) Al-Momani, Ayman H. "Construction delay: a quantitative analysis." *International journal of project management* 18.1 (2000): 51-59.

23) Assaf, Sadi A., and Sadiq Al-Hejji. "Causes of delay in large construction projects." *International journal of project management* 24.4 (2006): 349-357.

24) Osmani, Mohamed, Jacqueline Glass, and Andrew DF Price. "Architects' perspectives on construction waste reduction by design." *Waste Management* 28.7 (2008): 1147-1158.

25) Burati, J.L., Farrington, J.J. & Ledbetter, W.B., 1992. Causes of Quality Deviations in Design and Construction. Journal of Construction Engineering and Management, 118(1), pp.34.49.

26) Akinsola, A.. et al., 1997. Identification and evaluation of factors influencing variations on building projects. International Journal of Project Management, 15(4), pp.263–267.

27) Ibbs, W., 2012. Construction change : Likelihood, severity , and impact on productivity. Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, (August), pp.67–73.

28) Park, M., 2003. Dynamic Change Management for Fast-tracking Construction Projects, NIST.

29) 五艘隆志, 濱田成一, and 草柳俊二. "我が国の公共工事における甲乙協議および契約紛争解決プロセスに関する研究." *建設マネジメント研究論文集* 16 (2009): 173-182.

30) 大本俊彦, 小林潔司, and 大西正光. "請負契約約款の紛争解決手続きに関する比較検討." 建設マネジメント研究

論文集 9 (2002): 151-162.
31) 渡邊法美: リスクマネジメントの視点から見たわが国の公共工事入札・契約方式の特性分析と改革に関する一考察, 土木学会論文集F, Vol.62, No.4, pp.684-703, 2006.
32) Chan, Albert PC, and C. M. Yeong. "A comparison of strategies for reducing variations." Construction Management and Economics 13.6 (1995): 467-473.
33) Chang, Chen-Yu, and Graham Ive. "Reversal of bargaining power in construction projects: meaning, existence and implications." Construction Management and Economics 25.8 (2007): 845-855.