A Tentative Exploration of Incentives to Introduce Long Term Relationship between Construction General Contractor and Subcontractor from a Game-Chain Perspective

An Tingyu and Watanabe Tsunemi
Kochi University of Technology

ABSTRACT**:** One of urgent issues for sustainable development of the Chinese construction industry is argued to be developing capable specialty contractors in the downstream of supply chain. One valuable approach inspired from Japanese construction is argued to be building long-term relationship between General Contractor (GC) and a group of allied subcontractors (SCs). Then there comes a crucial issue as how to initiate and motivate the involved players to establish and maintain this cooperative business relationship, particularly under today's extremely competitive and uncertain business environment.

This study aims to explore the potential incentives of long term relationship. A tentative game-chain model was conducted on the psychological competition scenarios between GC and SC in the activity of resource allocating. In this model, maintaining a long term working relationship is interpreted as a chain of games, in which the former game will exert influence on the latter through the actions each player takes. As a result, the systematic equilibrium must be approached based on a holistic and dynamic thinking. The analytic results show that under an uncertain and dynamic situation in resource allocating, one-off game (as short-term work relationship) between GC and SC leads to the worst equilibrium, interpreted as cheating behaviors by both players. However, with the game repeating more times (forming a game-chain), the systematic equilibrium moves to honest behaviors by both players, with an increase in both utilities. It indicates that long-term relationship could provide with economic incentive for both players in their economic activities.

In future study, this approach needs to be evaluated more comprehensively, particularly on its potential demerits. For example, if SCs are too much "locked in" vertical relationship with GC, it might easily lead to SCs' inability to diversity and over-reliance. It again reveals the significance of more careful considerations on implementation practically.

KEYWORDS: long-term, incentive, uncertainty, game-chain, systematic equilibrium

1. INTRODUCTION

With regard to the industrial polices in the Chinese construction, up until now, those policies have mainly been oriented from the perspective of the industrial development, focusing on such issues as enhancing technical aspects of the industry, improving labor productivity, and increasing enterprises' efficiency, and so on. This can be seen in the reform and restructure of management in construction enterprises, as well as the introduction of the market mechanism into recruitment practices in the 1980s; the reform of state-owned enterprises (SOEs) and adjustments to the qualification requirements adopted in the late 1990s; and the promotion of mechanization and industrialization these years (Lu and Paul, 2001) . It is true to say that many good experiences have been accumulated with regard to the rapid development of construction industry in China. However, the negative effects on the potential on the job growth and employment situations have being occurred (Hu, 2002; Qian, 2004). This can be noticed from the increasing difficulties in retention and recruitment of the construction labor force in recent China, with a major reason that most construction laborers have still being suffering from the poor working and living conditions (Cai, 2009). It reveals that a labor-oriented industrial development strategy needs to be taken into consideration as soon as possible for developing Chinese construction sustainably. It lies in not only sustaining a stable level of employment, but in helping create the conditions of business success as well. It is certainly a complicated and systematic task to be tackled carefully.

One of the keys for developing Chinese construction sustainably is to truly understand the indispensable role of subcontractors in both construction production and employment improvement (An, 2012). And then, how to facilitate their continuous developments towards the capable specialty contractors in the downstream of supply chain becomes a crucial issue for both improving employment and production. Although the partnering under long term work relationship between General Contractor (GC) and a group of subcontractors (SCs) is argued to be an effective approach in many countries, however, under today's competitive and insecure business environment, how to motivate and initiate this approach is still a difficult task to be tackled in both academic and practical fields.

2. OBJECTIVE AND METHODOLOGY

Partnering or strategic alliance, as one of the cooperative mechanisms, has been frequently considered in part of value chain (among client, designer, and general contractor) for integration in real practice, whereas subcontractors are often left out of the key alliance. This paper particularly focuses on the alliance between general contractors and subcontractors, and how to motivate the involved players to establish and maintain this partnering business manner under long term relationship with regard to competitiveness and insecurity of business environment. Aiming at exploring the potential incentives of promoting alliance between general contractors and subcontractors, a tentative game-chain model was conducted on the psychological competition scenarios between GC and SC in their major activity of resource allocation.

3. BRIEF LITERATURE REVIEW

Under an unavoidable trend of subcontracting, despite of its merits and demerits, it has been agreed of the indispensability of subcontractors in construction production universally. **C**oncerning the relationship between general contractors and subcontractors, many countries have already practiced alliance under long term relationship between contractors and their subcontractors formally and informally for many years. However, whether this approach could be beneficial to those involved parties are still under arguments. Some of their experiences have shown that alliances under long term relationships could contribute or benefit the construction industry. Hoban and Francis (2002) found that most subcontractors consistently work for the same contractors and 94% of subcontractors in Australia have worked with not more than three major contractors. Regarding the cooperation years, 41% of commercial subcontractors have been found to maintain steady relationships with their general contractors for an average of 9.2 years (Costantino and Pietroforte, 2002). In Japan, this practice is more prevalence, regarding the fact that each giant general contractor has its exclusively allied subcontractors (*kyoryokukai* in Japanese). And it has been regarded as one crucial factor contributing to the highly specialized Japanese construction industry with abundant small scale subcontractors, who have high level of construction skills and techniques (Bennett et al., 1987). However, there are still arguments on partnering or alliances cannot provide those involved parties with any competitive advantage over other competitors. Take Australia for example, although strategic alliance has been promoted by government, it was demonstrated to be associated with a negative impact on business performance (Kwok, 1997). Regarding the practice, many scholars argue that long term relationship is prone to adoption by SCs just as a short-term response to the pressure from powerful clients or GCs, rather than a fundamental cultural change. Moreover, if it is not implemented properly, it could exert detrimental effects on SCs in turn. The real cultural change requires a true understanding of factors that dictate the basic interests of the parties involved (Bresnen and Marshall, 2000). Thus, to explore the benefits from long term relationship has practical significance, particularly for GC and SCs in their major activity in allocating resources.

4. MODELLING AND ANALYSES

Alliance of mutual trust between players can be seen as a successful cooperation game process. From the long-term view, only repeated games could reduce the happening of opportunistic behavior (to be dishonest), and increase the trust of partners when unpredictable events occur. Hence, a win-win supply chain alliance could be achieved. We will analyze the following simple game chain model to illustrate that continuous transactions under long term relationship will enhance the trust working culture.

In this section, we will exemplify the behaviors of GC and SC through modeling the resource allocation in a series of games (forming a game chain). Intuitively, the behaviors of GC and SC are interrelated, and the behaviors in present work relation must have influence on the judgments in the possible next work relation between them. However, in practice, it seems not yet considered seriously by players. An empirical observation is that many downstream subcontractors in China seem only focus on gaining present (short-term) profits as far as they can, even with cheating behaviors that ruin the working culture within the construction supply chain. It lacks a strategic perspective on business development with regard to possible market shares by continuous transactions in the long run.

4.1 Formulation of game-chain scenario between GC and SC

We assume that GC and SC have no working relation before and it is also unknown that whether they would work together next time. Given that the contract price between client and GC is reasonable enough in each project so that GC does not have to worry about its payment by client. What GC should be concerned with is how to complete the work efficiently with SC's cooperation in each project. Decisions influenced by this concern must be different from a short-term (one-off) or long-term perspective, which will be explained later.

In the activity of resource allocation in a project, regarded as a game unit, SC tends to provide fewer resources, which is commonly acknowledged in practice by project manager from GC. In order to counteract this situation, GC would demand more resources than needed consequently. Intuitively, this would have a predictable result of damaging SC's confidence in resource allocation, which will exacerbate the problems over time, and lead to lose-lose and non-trust working culture. That is to say, subcontracting in construction production is actually a series of games. In each round of game, GC (buyers) and SCs (sellers) seek to optimize their returns by demanding resources and allocating resources in projects.

However, it must not be neglected that the result of former game would exert influence on the judgement or decision process in the latter game. So the continuous transactions actually could be interpreted as a chain of games in which the former game exerts influence on the latter based on the action each player takes. Consequently, any rational player should not only consider the immediate reward but also take the long-term benefit into consideration. In plain terms, today's decision will influence tomorrow, and tomorrow's decision will influence future as well. If you disregard the impacts on future and only take the interests of current stage into account, you actually do not make a wise decision seen from the long-term perspective. Thus, the systematic equilibrium of game chain must be approached from a holistic way of thinking.

Then we form the following game chain in a general way (only two rounds of games will be analyzed here) (see figure 1), in which I_1 denotes the influence on the 2nd round game, which is exerted by the equilibrium E_1 of the 1st round game. Here E denotes the systematic equilibrium of game chain, the result from a holistic point of view by both rational players. The utility of game unit i is denotes as u_i (i=1,2).

4.2 Analyses on one-off game

To find the systematic equilibrium, one-off game will be analyzed firstly. One-off game here exemplifies the scenario that both players only concern short-term benefit in a one-off work relation, with no consideration of any possible cooperation next time.

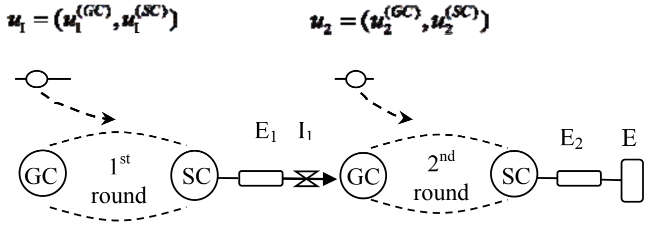

Figure 1 A two-unit game-chain of GC and SC in the activities of resource allocation

4.2.1 Moves of players

In each round of game, two players make "moves" one after the other through the repeated cycles of the game. To be detailed, GC will set the work amount ($W_{demanded}$) that is to be performed by SC in each period based on the work plan ($W_{planned}$). In response, a rational SC will evaluate the amount of work demanded will actually become available ($W_{available}$), and then take actions to supply the proper amount of resources ($R_{provided}$). Since the actions are taken sequentially, this process turns out to be a series of dynamic games. What is needed to stress here is that both GC and SC have imperfect knowledge about the outcome in terms of the work amount that will actually be completed until it happens.

4.2.2 Impacts of work plan reliability q

This one-off game in each round between GC and SC is a dynamic game with incomplete information. In this game, the project manager from GC must take an action with imperfect knowledge of the actual work amount that is made available. Similarly, the subcontractor also has imperfect knowledge about whether the project manager from GC has demanded more, exact or fewer resources than necessary. In a word, the actions set of GC and SC is supposed to be greatly influenced by the degree of their perceptions on the actually available work amount, regarded as the work plan reliability denoted here as q. It must be known that the work plans are not always necessarily reliable. In other words, it is often unknown with uncertainty $P_r(q)$ at the beginning of each period, meaning that the actual value of q occurs with uncertainty $P_r(q)$ in practice.

4.2.3 Harsanyi transformation with information set

Information set is used here to explore the impact of plan reliability on the expected behaviors of GC and SC with regard to plan reliability. It will then make it possible to model the scenario in which each player either knows or does not know the variable value of 'nature' (*N*), in this case the value of *q*, which measures the amount of work that will actually become available. In this scenario, the incomplete game between GC and SC will then be converted into two stages of dynamic games via Harsanyi transformation (see figure 2).

GC's possible actions are detailed at the second level by *d*, which represents the ratio of the work demanded to the work that GC estimates will actually become available. Here, the value of *d*, will be modeled by discrete values: demand for less work amount than estimated (*d*=0.9), exactly the amount estimated (*k*=1), and more than estimated (*d*=1.1). In response to GC's demand, SC can select the amount of resources to be allocated according to the amount required for the work demanded. Here, *k* represents the radio of resources supplied to those demanded (*k*=0.9), exactly the amount required (*k*=1), or more than demanded (*k*=1.1).

$$q = \frac{W_{Available}}{W_{planned}}$$

$$d = \frac{W_{demanded}}{W_{planned}}$$

$$k = \frac{R_{provided}}{R_{demanded}}$$

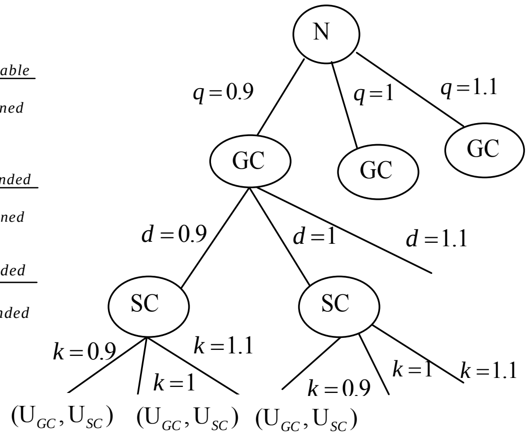

Figure 2 The one-off game between GC and SC by Harsanyi transformation

4.2.4 Pay-off matrix and equilibrium

Given the unit price for the work set (*U*) in the subcontract, the unit costs of materials (C_M), and the cost of resources per units of work planned (C_S), the payoff matrix of this one-off game between GC and SC under the information sets of plan reliability is shown in Table 1 (An, 2012). The equilibrium of this one-off game is (1.1, 0.9), which means that in the one-off game (a short-term work relation), GC is likely to demand more resources, and SC is prone to supply with fewer resources eventually. It is a frustrating result, since both of players have not achieved their optimum utilities, and also the collective optimum utility.

Table 1 Payoff matrix of the one-off game between GC and SC

GC \ SC	**0.9**	1.0	**1.1**
0.9	$(0.81, 0.81(U-C_M)-0.9C_S)$	$(0.9, 0.9(U-C_M)-C_S)$	$(0.963, 0.963(U-C_M)-1.1C_S)$
1.0	$(0.9, 0.9(U-C_M)-0.9C_S))$	$(0.97, 0.97(U-C_M)-C_S)$	$(0.98, 0.98(U-C_M)-1.1C_S)$
1.1	$(0.963, 0.963(U-C_M)-0.9C_S)$	$(0.98, 0.98(U-C_M)-C_S)$	$(0.98, 0.98(U-C_M)-1.1C_S)$

4.3 Analyses on the two-unit game-chain

Regarding that the happening possibility of next work relation is passively perceived in the previous one-off game, both players are only interested in the present or immediate benefits. However, with the game repeating many times, the result may move towards different one. Under long term relationship with continuous transactions, intuitively, players are likely to give up the opportunistic behaviors of cheating each other, and choose a different strategy to pursue for overall benefits.

Let's go back to the two-unit game-chain shown in figure 1. Both players actually know how their decisions in the former game will influence the action in the latter one. As a result, what they concern is not only the benefit at present, but the overall benefits of all possible transactions between them. A rational player would follow the principle of tit-for-tat, meaning that if both players choose to cooperate in the first round of the game, the subsequent round will repeat with the same strategy; if the player chooses to cheat, the other will choose to cheat in the subsequent game as well. Therefore, in this gaming process, a rational player is supposed to take into account of the fact that the "partner" may retaliate in the subsequent round.

To approach to the systematic equilibrium of this game chain, analyses are simply divided into two parts with regard to different types of subcontracting market:

Market Type I: demand exceeding supply

Market Type II: supply exceeding demand

Then, the influences of the former game on the latter one are interpreted in the table 2 and table 3, followed with pay-off matrixes as the table 4 and table 5 respectively. Here, δ_i (i=1,2,3) denotes the discount factor in the 2nd round game ($0<\delta_i<1$). The value of δ_1 is the smallest, because the cheat behaviors by both will lead to the worst result in the 2nd game. C_j (j=1,2) denotes the cost of participating in another work relation as a result of cheating behavior in the former work relation.

Table 2 Interpretations of influences under market I

Actions (R_1)	Influences (I_1)	Following Actions (R_2)
(0.9,0.9)	Dishonest SC	(1.1,0.9) with δ_1
(0.9,1.0)	Trustful SC	(1.0,1.0)
(0.9,1.1)	Negotiation	(1.0,1.0)
(1.0,0.9)	Dishonest SC	(1.1,0.9) with δ_1
(1.0,1.0)	Both trustful	(1.0,1.0)
(1.0,1.1)	Trustful GC	(1.0, 1.0)
(1.1,0.9)	Both dishonest	(1.1,0.9) with δ_1, C_1
(1.1,1.0)	Dishonest GC	(1.0,0.9) with δ_2, C_1
(1.1,1.1)	Dishonest GC	(1.0,0.9) with δ_2, C_1

Table 3 Interpretations of influence under market II

Actions (R_1)	Influences (I_1)	Following Actions (R_2)
(0.9,0.9)	Dishonest SC	(1.1, 1.0) with δ_3, C_2
(0.9,1.0)	Trustful SC	(1.0,1.0)
(0.9,1.1)	Negotiation	(1.0,1.0)
(1.0, 0.9)	Dishonest SC	(1.1, 1.0) with δ_3, C_2
(1.0,1.0)	Both trustful	(1.0,1.0)
(1.0,1.1)	Trustful GC	(1.0,1.0)
(1.1,0.9)	Both dishonest	(1.1,0.9) with δ_1, C_2
(1.1,1.0)	Dishonest GC	(1.1,0.9) with δ_1
(1.1,1.1)	Dishonest GC	(1.1,0.9) with δ_1

As can be seen from table 4, in the market with demand exceeding supply, the game equilibrium must lie in the row of GC=1.0, given the value of C_1 is large sufficiently, and a small discount factor δ_1. It means that a rational GC should choose to be honest. And consequently a rational SC would like to be of integrity as well. Hence, through repeating game (interpreted as continuous transactions under long term relationship), the equilibrium moves to

(1.0, 1.0). Similarly, seen from table 5, in the market with supply exceeding demand, a rational SC will not choose *k*=0.9, given a sufficiently large value of C_2. Considering the discount factor of δ_1, we could easily find the equilibrium of this game is (1.0, 1.0). The analytic results tell that taking the total utilities of two round games into account, GC and SC will choose to be honest at the beginning. Thus, it could be concluded that long term relationship could provide with economic incentive to bring a win-win work relations and further trustful work culture between GC and SC.

5. CONCLUSION

The analytic results of model show that under an uncertain and dynamic situation in resource allocation, one-off game (as short-term work relation) between GC and SC leads to the worst equilibrium, interpreted as cheating behaviors by both players. However, with the game repeating more times (forming a game-chain), the equilibrium moves towards honest behaviors by both players. It indicates that long-term relationship could provide with economic incentive for both players in their economic activities, which could promote trustful working culture in the long run. However, this approach still needs to be evaluated more comprehensively, particularly on its potential demerits. For example, if SCs are too much "locked in" vertical relationship with GC, it might easily lead to SCs' inability to diversity and over-reliance. It again reveals the significance of careful considerations on practical implementation.

Table 4 Pay-off matrix of two-unit game-chain under market type I

GC \ SC	0.9	**1.0**	**1.1**
0.9	$(0.81, 0.81(U-C_M)-0.9C_S)$ $+\delta_1(0.963, 0.963(U-C_M)-0.9C_S)$	$(0.9, 0.9(U-C_M)-C_S)$ $+(0.97, 0.97(U-C_M)-C_S)$	$(0.963, 0.963(U-C_M)-1.1C_S)$ $+(0.97, 0.97(U-C_M)-C_S)$
1.0	$(0.9, 0.9(U-C_M)-0.9C_S))$ $+\delta_1(0.963, 0.963(U-C_M)-0.9C_S)$	$(0.97, 0.97(U-C_M)-C_S)$ $+(0.97, 0.97(U-C_M)-C_S)$	$(0.98, 0.98(U-C_M)-1.1C_S)$ $+(0.97, 0.97(U-C_M)-C_S)$
1.1	$(0.963, 0.963(U-C_M)-0.9C_S)$ $+\delta_1(0.963, 0.963(U-C_M)-0.9C_S)$ $-(C_1,0)$	$(0.98, 0.98(U-C_M)-C_S)$ $+\delta_2(0.963, 0.963(U-C_M)-0.9C_S)$ $-(C_1,0)$	$(0.98, 0.98(U-C_M)-1.1C_S)$ $+\delta_2(0.963, 0.963(U-C_M)-0.9C_S)$ $-(C_1,0)$

Table 5 Pay-off matrix of two-unit game-chain under market type II

GC \ SC	0.9	**1.0**	1.1
0.9	$(0.81, 0.81(U-C_M)-0.9C_S)$ $+\delta_3(0.98, 0.98(U-C_M)-C_S)$ $-(0,C_2)$	$(0.9, 0.9(U-C_M)-C_S)$ $+(0.97, 0.97(U-C_M)-C_S)$	$(0.963, 0.963(U-C_M)-1.1C_S)$ $+(0.97, 0.97(U-C_M)-C_S)$
1.0	$(0.9, 0.9(U-C_M)-0.9C_S))$ $+\delta_3(0.98, 0.98(U-C_M)-C_S)$ $-(0,C_2)$	$(0.97, 0.97(U-C_M)-C_S)$ $+(0.97, 0.97(U-C_M)-C_S)$	$(0.98, 0.98(U-C_M)-1.1C_S)$ $+(0.98, 0.98(U-C_M)-C_S)$
1.1	$(0.963, 0.963(U-C_M)-0.9C_S)$ $+\delta_1(0.963, 0.963(U-C_M)-0.9C_S)$ $-(0,C_2)$	$(0.98, 0.98(U-C_M)-C_S)$ $+\delta_1(0.963, 0.963(U-C_M)-0.9C_S)$	$(0.98, 0.98(U-C_M)-1.1C_S)$ $+\delta_1(0.963, 0.963(U-C_M)-0.9C_S)$

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