

# Potential benefits for collaborating formwork subcontractors based on co-operative game theory

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## Abstract

Formwork subcontractors that hire open shop workers, rather than union workers can win more contracts and earn more profits from general contractors because of greater agility and lower costs. A subcontractor may earn even more profit if it collaborates with others in a coalition. Payoff functions for individual subcontractors and a group of subcontractors in a coalition are formulated. Profit can also be reasonably allocated to each subcontractor in a coalition using the Shapley value and nucleolus. © 2004 Elsevier Ltd. All rights reserved.

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## 1. Introduction

The construction labor market has had a gradual, yet significant, change in the last few decades [1]. Construction labor unions had dominated the labor markets by providing high-quality skilled workers and being involved in systematic labor training for industries for a long time [2]. The high costs and the lack of communication with general contractors of the union workers, however, have jeopardized their relationships with general contractors [3]. On the other hand, open shop workers, with their agility and cost competitiveness are taking over a larger and larger share of the construction labor market [4]. As a result, many skilled workers have left unions and become self-employed open shop workers or employees of specialty subcontractors [5]. Little, however, has been discussed about the size, contracting

capacity and corresponding differences in the costs of subcontractors that hire open shop workers.

Electric power supply markets shared a similar historical change path with the construction labor market [6]. Public utilities had been the sole sources supplying electricity in many nations for a long time [7]. Due to lower costs, many independent power producers are taking over more and more power supply market shares from the public utilities [8]. Research reveals that joining of independent power producers in a coalition can reduce costs even more, and improve profits [9]. Lessons learned in the power supply market changes and from the co-operative strategy of independent power producers may be useful for strategic planning in improving profitability for independent subcontractors that hire open shop workers.

In-depth interviews are presented herein to identify the business model of formwork subcontractors, as well as, to explore changes in the unit cost of formwork with respect to daily production rates of each subcontractor. Game theory is then applied to investigate the possibility of optimizing unit cost and improving profitability by joining several independent subcontractors in a coal-

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tion. Nucleous and Shapley Value are also suggested for allocating profits among the coalition.

## 2. The business model of the formwork subcontractor

Formwork is a temporary facility used to construct a permanent reinforced concrete structure. Costs for formwork, including labor and material, often take up some 60% of the cost of a reinforced concrete structure [10].

Three in-depth interviews were carried out in this research to identify the business model and to formulate cost functions for formwork subcontractors. According to the aforementioned interviews, the business model for the formwork subcontractor can be summarized as follows.

Subcontracting or outsourcing is one of the most common practices adopted by general contractors in sharing project risks and surviving in the volatile business cycle [11]. The number of subcontracts is a function of the project characteristics including size, technical complexity, and scattering operations [12]. Manageability and contracting capability of subcontractors are also crucial factors in splitting a single work item into several subcontracts [13]. With very few exceptions, the decisions as to whether to split a single work item into several subcontracts or not are made by the general contractors without the knowledge of whether these decisions will be cost effective for the formwork subcontractors or not [14].

The business of the formwork subcontractors often comes from selective bids administered by general contractors that keep a long and/or short list. Sometimes, the formwork subcontractor has to attend open bids to get business. Other times, the subcontractor may also get business from a negotiation procedure. Previous quality records and word of mouth are the bases to attract invitations from general contractors. Cost competitiveness is, however the key factor to gain business.

As the modularized formwork systems are becoming popular, rental material is becoming more and more available and is separated from the business of formwork subcontractors nowadays [15]. Labor-only subcontracting offers economic advantages to both the general contractors and subcontractors. The former avoid the mark-up of full subcontracting and the latter do not incur the initial cost for mobilization and purchasing materials [13]. Discussions in this paper shall concentrate on subcontractors that offer labor-only business service.

Formwork workers get paid only when they are on a job. Groups of skilled workers often co-operate together to bid on jobs from general contractors. Some of the formwork subcontractors hire skilled workers on a

regular basis. Although some regularly hired workers may get paid a monthly salary, most workers get paid a daily wage based on the days worked.

## 3. Co-operative game theory in brief

### 3.1. Game theory in general

The participation of formwork subcontractors in a competitive market is similar to players' participation in a game. Non-cooperative and co-operative game approaches are two common categories discussed in Game theory [16]. The former is relevant to a situation where a decision-making unit in a market treats the others as competitors, while the latter deals with a situation in which a group of decision-makers decide to undertake a project together—all partners joining the project being regarded as collaborators—in order to achieve their joint business objectives: for example, to increase total revenue (profit maximization) or market shares or to decrease total costs (cost minimization) [17]. Two classes of co-operative games are those in which utility can be transferred (TU-games), and those in which utility cannot be transferred (NTU-games) [18].

### 3.2. Fundamentals of co-operative games

Game theory assumes that a player evaluates various outcomes in terms of the utility derived from them [19]. There are two key points in a co-operative game: (1) what is the payoff for each coalition? and (2) what payoff each player in the coalition should get [20].

The benefits acquired by the different members of the various coalitions are different [19]. Consistent with the definition of co-operative games, if the profit gained by a co-operating player exceeds that which would be gained when acting independently, that player will certainly seek to establish a coalition.

The method adopted for allocating benefits and costs among the members will affect the willingness of various members to remain active in the coalition. The allocation problem may be solved in a variety of ways, but an allocation rule that prescribes, somehow, a solution for the allocation problem should satisfy desirable criteria such as efficiency, fairness and others [21]. The Shapley value and the nucleolus are the two best known solution concepts which fit the aforementioned criteria [22,23].

### 3.3. The shapely value

The Shapley value is the expected marginal amount contributed by a player to a coalition [24]. This method is based on the potential fairness of the distribution of the total benefit achievable by the coalition [25,26].

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