# A Two-Level Programming Method for Collaborative Scheduling in Construction Supply Chain Management

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**Abstract.** There are increasing requirements for collaborative scheduling (CS) in supply chain management (SCM). CS in construction supply chain (CSC), which involves multiple partners, such as general contractor, subcontractors, and material suppliers, can be seen as a multilevel decision-making system with hierarchical structure. Adopting the decomposition-coordination thought of large scale system theory and using the multilevel programming theory, a two-level programming model for CS decision making is established to find satisfactory solution for every partner in CSC. This model has the merit of paying attention to the maximization of profit or minimization of cost of all partners located at different decision-making level in CS process. The algorithm of this model is provided, which is combined with the first level programming adopting simulated annealing algorithm and second level programming using discrete search algorithm. Finally, an illustrative example of CS in a CSC is presented. The two-level programming method provides a new way to improve collaborative decision making in CSC. This research makes a contribution to the body of knowledge of scheduling.

**Keywords:** Collaborative scheduling, Two-level programming, Supply chain, Construction industry.

## 1 Introduction

Effective supply chain management (SCM) has become a potentially valuable way of securing competitive advantage and improving organizational performance since competition is no longer between organizations, but among supply chains. Applications of SCM in manufacturing environments have saved hundreds of millions of dollars while improving customer service [1]. With the increasing interests in applying SCM principle, which focuses on collaborative decision-making in business operations, to the construction industry [2], [3], collaborative scheduling (CS), one of the crucial operation problems in construction supply chain (CSC) management, has become an emerging managerial demands beyond traditional construction scheduling method from an independent view of a firm.

Y. Luo (Ed.): CDVE 2007, LNCS 4674, pp. 290–297, 2007.

Scheduling is concerned with the optimal allocation of scare resources to activities over time. It is very attractive for researchers, with an impressive amount of literature as the result, because it's obvious practical importance. However, scheduling problems, in general, are really challenging from a computational point of view with the increasing complexity of decision-making environment. In the construction community, a lot of attempts have also been made to solve the construction scheduling problem, for example the work carried out by [4], [5], [6], [7]. Most of the above models or methods can generally be called approach to classical resource-constrained project scheduling problem [8].

CSC is a construction business system involving multiple stakeholders [9]. Considering the constraints of capability and resource, CSC is not governance structure to autonomously pursue maximum benefit in global chain domain from the perspective of principle-agent theory. Coordination mechanisms should be applied to the operational process of CSC to achieve global optimization, which is a result in centralized decision-making [10]. This research adopts CS as a coordination mechanism to improve collaborative decision-making performance.

CS problem in CSC is a typical multiple level programming problem. Adopting the decomposition-coordination thought of large scale hierarchical system theory, a two-level programming model for CS decision making is established to find satisfactory solution for each partner.

## 2 Hierarchical Decision-Making in CSC

CSC consists of multiple decision units involved in the construction process, such as client/owner, designer, GC, subcontractor, and suppliers. CSC system is typical hierarchical system in which general contractor is located at the upper level (leader) and subcontractor or supplier is located at lower level (follower), as shown in Figure 1. The hierarchical decision-making characteristics of CSC are described as follows.

(1) CSC is organized in a 'taper' structure with multiple decision units including general contractor (GC), subcontractor (designer also can be seen as one kind of subcontractor), suppliers and suppliers' supplier.

(2) GC, subcontractor and supplier make decision in turn, especially in project scheduling, but subcontractor and supplier have considerable decision power independently.

(3) Information is exchanged between difference levels in CSC. But the information from upper level to lower level has priority. For example, GC's information is prior to subcontractors. Subcontractors should abide by GC's 'order' if possible.

(4) Decision maker is located at higher level more interesting to long time goal. GC firstly makes decision, for example making master project scheduling, then subcontractor or supplier makes decision on the condition of complying with GC's decision.

(5) CSC has the global goal systems, for example, quality, cost, time, safety, and environment. The goals of whole decision makers should be coordinated.