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Integrated Game-Theory Modelling for Multi Enterprise-Wide Coordination and Collaboration under Uncertain Competitive Environment

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Abstract

In this work, an integrated Game Theory (GT) approach is developed for the coordination of multi-enterprise Supply Chains (SCs) in a competitive uncertain environment. The conflicting goals of the different participants are solved through coordination contracts using a non-cooperative non-zero-sum Stackelberg game under the leadership of the manufacturer. The Stackelberg payoff matrix is built under the nominal conditions, and then evaluated under different probable uncertain scenarios using a Monte-Carlo simulation. The competition between the Stackelberg game players and the third parties is solved through a Nash Equilibrium game. A novel way to analyze the game outcome is proposed based on a win-win Stackelberg set of "Pareto-frontiers". The benefits of the resulting MINLP tactical models are illustrated by a case study with different vendors around a client SC. The results show that coordinated decisions lead to higher expected payoffs compared to the standalone case, while also leading to uncertainty reduction.

Keywords: Decentralized multi-participant SC, Coordination, Game Theory, Uncertainty, Competition, Pareto-frontiers.

1. INTRODUCTION

The dynamic competitive nature of the Supply Chain (SC) underscores the interest of the Process System Engineering (PSE) and Operations Research (OR) communities in the SC optimization considering all participants (decentralized decision-making). Such approach should take into consideration individual and global objectives in order to achieve the Enterprise-Wide Optimization (EWO) (Hjaila et al., 2015, 2016a). A SC is a set of entities distributed along different sites to produce intermediate/final products for other SCs and/or final markets (Figure 1). SC tactical managers aim to synchronize and coordinate the resources (physical/economic) and information flows among the SC entities over a specified planning horizon, so as to ensure profitability for the entire company/companies. When the tactical decisions of a SC are synchronized under a common objective function of a single enterprise, a centralized SC takes place (Hjaila et al., 2016b). However, a decentralized SC network takes place when the SC entities belong to different enterprises, the tactical decisions have to be synchronized under the different goals set by the different enterprises involved (Hjaila *et al*., 2016a). A decentralized SC is represented in Figure 1. The dashed arrows represent the economic sales for one SC enterprise and cost for other SC enterprise, and thus a conflict of interest arises and the whole system becomes difficult to coordinate, especially in