



# An agent-based negotiation model for supplier selection of multiple products with synergy effect



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## ABSTRACT

Supplier selection is an important problem in supply chain management (SCM), and has attracted the attention of many researchers. Tremendous effort has been spent on the development of agent-based systems to automate supplier selection negotiation process in SCM applications. In this kind of multi-agent system (MAS), software agents are established to represent various parties and functions involving in the supplier selection negotiation process. Most of current systems only deal with relatively simple negotiations involving the acquisition of one product, they are not sufficient to support complex negotiations involving multiple products with synergy effect. However, in practice, it is common for a purchasing company to procure multiple products simultaneously, and the synergy effects that exist between products could affect the final choice of cooperative suppliers. This paper presents an agent-based negotiation model to automate the supplier selection process involving a bundle of products with synergy effect. A MAS is established to realize the proposed negotiation model for multi-product supplier selection. Furthermore, the negotiation proposal, negotiation protocol, negotiation strategies, and decision making methods involving in the negotiation model are elaborated for the multi-product supplier selection environment. Through the proposed negotiation model, the purchasing company and suppliers can reach agreements on the details of products simultaneously and exploit the synergy effect between products. Finally, illustrative examples are conducted to demonstrate the function and effectiveness of the negotiation model for multi-product supplier selection.

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## 1. Introduction

Nowadays enterprises usually outsource some non-core activities and focus on core activities to reduce cost and enhance competitive capabilities (Chopra & Meindl, 2007). Then the competition between enterprises has evolved to competition between supply chains. Consequently, the performances of member enterprises determine the success of supply chain, and supplier selection becomes an important problem of supply chain management (SCM).

Supplier selection is the process of finding the suitable suppliers who can provide the buyer with the right quality products/services at the right price, in the right quantities and at the right time (De Boer, Labro, & Morlacchi, 2001). Supplier selection involves activities to solve the conflicts between the buyer and suppliers on the details of products/services. For supply chain members with conflicting interests or viewpoints, negotiation is an essential

approach for decision makers to reach mutual agreements (Wang, Wong, & Wang, 2013). Supplier selection negotiations may involve a wide range of details of products/services, including price, quality, delivery time, service, and so on.

As a novel approach of business automation, agent-based systems are being increasingly used in SCM applications, involving supply chain formation (Kim & Cho, 2010), supply chain risk management (Giannakis & Louis, 2011), virtual supply chain networks (Long, 2014), etc. Regarding the features of autonomous, cooperative and pro-reactive, the agent-based systems are suitable to automate supplier selection negotiations (Kim & Cho, 2010; Wang et al., 2013; Wang, Wong, & Wang, 2012; Wong & Fang, 2010). Within an agent-based system for supplier selection negotiation, software agents are established to represent various parties and functions involving in the buyer–seller interaction process.

However, existing agent-based negotiation models for supplier selection are studied under the following two assumptions: firstly, products are negotiated one by one and cannot be negotiated simultaneously; secondly, the products are independent and the synergy effects between products are not considered. In practice,

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it is common for enterprises to procure multiple products simultaneously, synergy effect which is an effect arising between two or more items that produces an effect greater than the sum of their individual effects (Tanriverdi & Ruefli, 2004), could exist in the multi-product supplier selection environment. Furthermore, both the purchasing company and supplier can benefit from the positive synergies between products, and the synergy effect between products can affect the final choice of cooperative suppliers. For instance, it is advantageous for the purchasing company to procure products with positive synergies together to reduce cost and improve efficiency, and it is common for suppliers to supply products with positive synergies together at a lower price to increase the chance of winning bids.

Therefore, the objective of this paper is to propose an agent-based negotiation model to support multi-product supplier selection, in consideration of the synergy effect between products. Firstly, a multi-agent system (MAS) will be established to realize the proposed negotiation model. Secondly, the negotiation proposal, negotiation protocol, negotiation strategies, and decision making methods involving in the negotiation model will be elaborated for the multi-product supplier selection environment. Thirdly, through the proposed negotiation model, the purchasing company and suppliers will reach agreements on the details of products simultaneously and make full use of the synergy effect between products.

The rest of the paper is organized as follows. Section 2 reviews literature on supplier selection, and agent-based negotiation models. Section 3 introduces the agent-based negotiation model for multi-product supplier selection, in consideration of the synergy effect between products. The computational elements in the negotiation model, for instance, negotiation objects, utility functions, negotiation decision functions, winner (cooperative suppliers) determination method, and so on are proposed in Section 4. Experiments are conducted in Section 5 to demonstrate the function and effectiveness of the agent-based negotiation model for supplier selection of multiple products with synergy effect. Finally, conclusion and future work follow in Section 6.

## 2. Literature review

### 2.1. Supplier selection

Supplier selection consists of analyzing and measuring the performances of a set of suppliers on multiple selection criteria by decision making methods. The selection criteria and decision-making methods are the two main elements in supplier selection problem. The review studies on selection criteria (Weber, Current, & Benton, 1991; Wilson, 1994) pointed out that selection criteria vary according to application scenarios, and decision makers should adopt appropriate selection criteria based on their specific scenarios. However, they also presented that price, quality, delivery and service are the most frequently used selection criteria in supplier selection process. In this research, these criteria are adopted to evaluate suppliers.

Most studies on supplier selection have been focused on the decision making methods. De Boer et al. (2001) presented a review of decision methods reported in the literature for supporting supplier selection process. Ho, Xu, and Dey (2010) analyzed the decision making approaches for supplier selection based on journal articles from 2000 to 2008. Chai, Liu, and Ngai (2013) provided a systematic review on articles published from 2008 to 2012 on the application of decision making techniques for supplier selection. Researchers viewed supplier selection problem as a multi-criteria decision making (MCDM) problem that involves the trade-offs between conflicting qualitative and quantitative

criteria, and pointed out that there is no common best way to evaluate and select suppliers, decision makers should adopt suitable decision making methods according to their specific scenarios.

Organizations use a variety of different approaches in their supplier selection processes. Sharma and Balan (2013) proposed an integrative approach considering Taguchi's loss function, technique for order preference by similarity to ideal solution (TOPSIS) and multi-criteria goal programming, to select relatively better performing supplier. Deng, Hu, Deng, and Mahadevan (2014) proposed a D-AHP method for the supplier selection problem based on D numbers which is a new effective and feasible representation of uncertain information. Karsak and Dursun (2014) proposed a novel fuzzy multi-criteria group decision making framework for supplier selection integrating quality function deployment and data envelopment analysis (DEA). In this research, a purchasing company can select suppliers for multiple products simultaneously and the purchasing company and suppliers can negotiate the details of products according to their preferences on products with synergy effect. Therefore, the supplier selection methods suitable for this scenario should be proposed.

The multi-product supplier selection is an emerging trend in current research. Feng, Fan, and Li (2011) proposed a decision method for selecting a pool of suppliers for the provision of different service process/product elements. Kim and Wagner (2012) addressed the supplier selection problem from the perspective of product configuration. Esmaeili Aliabadi, Kaazemi, and Pourghannad (2013) presented an integrated multi-item supplier selection model, and developed a novel two-level GA to solve the model. Kilic (2013) developed an integrated approach including fuzzy TOPSIS and a mixed integer linear programming model to select the best supplier in a multi-item/multi-supplier environment. Although these researchers proposed supplier selection for multiple products, they did not incorporate the synergy effect between products in supplier selection process. In practice, purchasing companies may express complementary or substitutable preferences over products, and the synergy effect between products could affect the final choice of cooperative suppliers. This research will propose a multi-product supplier selection model considering the synergy effect between products to fill this research gap.

### 2.2. Agent-based negotiation models

In the context of artificial intelligence (AI), a commonly adopted definition of agent is the notion proposed by Wooldridge and Jennings (1995): "an agent is a computer system that is situated in some environment, in which it is capable of autonomous action, in order to meet its predefined objectives". A multi-agent system (MAS) can be defined as a loosely-coupled system composed of multiple interacting agents that work collectively through cooperation or competition to solve problems that would be beyond their individual capabilities (O'Hare and Jennings, 1996). In the MAS domain, negotiation has been perceived as the most fundamental and powerful mechanism for managing inter-agent dependencies at runtime (Jennings et al., 2001). Through negotiation, a group of agents could reach mutually acceptable agreements on some matters.

For a supply chain, it is practical for the purchasing company and suppliers to negotiate on the details of products. A series of studies were conducted to automate supplier selection negotiation through the agent-based negotiation models. Cakravastia and Takahashi (2004) proposed a multi-objective model to support the process of supplier selection and negotiation that considers the effect of these decisions on the manufacturing plan. Kim and Cho (2010) used agent negotiation as a way to allocate numerous orders to many participants for supply chain formation. Wong and Fang (2010) presented ECNPro (the Extended Contract-Net-

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