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A hybrid agent-based computational economics and optimization approach for supplier selection problem

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ABSTRACT

Supplier evaluation and selection problem is among the most important of logistics decisions that have been addressed extensively in supply chain management. The same logistics decision is also important in freight transportation since it identifies trade relationships between business establishments and determines commodity flows between production and consumption points. The commodity flows are then used as input to freight transportation models to determine cargo movements and their characteristics including mode choice and shipment size. Various approaches have been proposed to explore this latter problem in previous studies. Traditionally, potential suppliers are evaluated and selected using only price/cost as the influential criteria and the state-of-practice methods. This paper introduces a hybrid agent-based computational economics and optimization approach for supplier selection. The proposed model combines an agent-based multi-criteria supplier evaluation approach with a multi-objective optimization model to capture both behavioral and economical aspects of the supplier selection process. The model uses a system of ordered response models to determine importance weights of the different criteria in supplier evaluation from a buyers' point of view. The estimated weights are then used to calculate a utility for each potential supplier in the market and rank them. The calculated utilities are then entered into a mathematical programming model in which best suppliers are selected by maximizing the total accrued utility for all buyers and minimizing total shipping costs while balancing the capacity of potential suppliers to ensure market clearing mechanisms. The proposed model, herein, was implemented under an operational agent-based supply chain and freight transportation framework for the Chicago Metropolitan Area.

Introduction

Supplier evaluation and selection problems are among the most crucial logistics decisions that have been addressed extensively in supply chain management. For many business establishments, raw material purchases and its affiliated

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transportation account for a large percentage of their total operating costs. This logistics decision is also important from the freight transportation perspective since it can affect other logistical choices, related to supply chain and freight transportation, such as mode and shipment size choices. Results of the supplier evaluation and selection decision identifies trade relationships between business establishments and determines commodity flows between production and consumption points in the supply-demand market. These commodity flows are then used as input to freight transportation models to determine cargo movements and their characteristics including mode choice and shipment size.

Various approaches have been proposed and employed to explore the supplier selection problem process in previous studies. Traditionally, potential suppliers are evaluated using only price/cost as the main criteria and state-of-practice methods, such as standard optimization approaches, are utilized to identify best suppliers and form optimum supply chains. However, a review of literature revealed that selecting suppliers or vendors offering the lowest price is not "efficient sourcing" and does not necessarily result in the least total logistics cost (Lung Ng, 2008; Dulmin and Valeria, 2003). In modern-day supply chain management, multiple factors are analyzed during the suppler evaluation and selection process. Moreover, these traditional approaches cannot capture the complex behavioral interactions among decision makers in the supply-demand markets and determine how buyers make discrete choices about from which suppliers to purchase the necessary raw material. This has made the supplier selection problem more complicated than ever before.

Literature examination showed that numerous quantitative approaches incorporating multi-criteria have been proposed. Multi-objective OPtimization (MOP) (Haleh and Hamidi, 2011; Yu et al., 2012), Analytic Hierarchy Process (AHP) (Levary, 2008; Mafakheri et al., 2011), Data Envelopment Analysis (DEA) (Wu and Blackhurst, 2009; Falagario et al., 2012; Saen, 2010) and Simple Multi-Attribute Rating Technique (SMART) (Huang and Keska, 2007; Chou and Chang, 2008) are among the most commonly implemented multi-criteria methods used to evaluate and choose the best suppliers for a supply chain. All the aforementioned methodologies have their advantages (*do you give the disadvantages as well*?). However, most of these approaches are based on traditional theories in which the behavioral elements of the supplier selection process are overlooked. In addition, preferences and beliefs of decision-making agents are not captured.

This paper introduces a hybrid Agent-based Computational Economic (ACE) and optimization approach for the supplier selection dilemma. The proposed model combines an agent-based multi-criteria supplier evaluation with a multi-objective capacity constrained optimization model to capture both behavioral and economical aspects of the supplier selection process for diverse markets. In the ACE approach, individual agents make supply chain decisions and interact with each other based on simple assumptions and rules in a simulated world. The model, propositioned in this paper, is an ACE methodology that captures how buyers will make discrete choices about who to purchase from based on their preferences and to maximize benefits while the model formulation ensures that supplier markets are optimal and Pareto efficient where each buyer cannot improve their condition without deteriorating another buyers' condition.

Our model uses a system of ordered response simulations to determine importance weights of criteria such as cost, distance and reliability for evaluating suppliers from a buyers' vantage point. Pourabdollahi et al. (2014). Using the estimated importance weights and the value of measure under each criterion, for each potential supplier a utility value is determined that represents the utility accrued by buyer if a potential supplier is selected. Each buyer can then rank, the potential suppliers based on the calculated utilities. The estimated utilities enter a mathematical programming model in which best suppliers are selected by maximizing the total accrued utility allotted by buyers and minimizing total shipping costs. This safeguards that the allocation of suppliers between buyers is a Pareto Efficiency state in which it is impossible to make a buyer better off without making, at least, another buyer worse off. Furthermore, the model applies the market-clearing process by considering the capacity of suppliers and demand of buyers as constraints, so that total demand of buyers are met without exceeding the capacity of any suppliers or leftover of supplies.

In summary, the proposed study incorporates behavioral ACE mechanism in supplier evaluation and combines it with the standard constrained optimization approach to develop a hybrid model that encapsulates the behavioral aspects of the decision-making process in selecting suppliers by considering both buyers and suppliers characteristics, as well as the economic aspects of the supply-demand market by including logistics costs and production capacity of suppliers – all within in the structure of the optimization model. The suggested model was implemented under an operational supply chain and freight transportation model for the Chicago Metropolitan Area in which supply chains are simulated at a highly disaggregated firm-level (Pourabdollahi, 2015).

The remainder of the paper is organized as follows. First, a brief review of existing studies on supplier evaluations and the selection problem is furnished. Secondarily, is the methodology and model framework. It briefly discusses the system of ordered logit models described herein (Pourabdollahi et al., 2014) and applied to determine utility values associated with potential suppliers. Also, market clearing algorithm and optimization model formulation is described. Moreover, the datasets for model development and estimation are discussed. Finally, the model implementation is described and some examples of model application are presented.

Literature review

Weber et al. (1991) analyzed and evaluated over 74 studies related to supplier selection criteria and methodologies to classify the most important factors in supplier evaluation while taking into account any significant changes in logistics and supply chain management process. They argued that supplier selection process has changed considerably due to recent evolvements in logistics and supply chain management, specifically in areas, such as: improved computer communications,

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