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A Pareto supplier selection algorithm for minimum the life cycle cost of complex product system

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ABSTRACT

Supplier selection has significant impact on life cycle cost of complex product system (CoPS). In this paper, a new variant of supplier selection problem named life cycle supplier selection of CoPS (LSS&CoPS) problem is addressed. There are three kinds of choices for a manufacturer to complete a CoPS: self-made, purchasing the finished component and outsourcing. Different selection not only results in difference of procurement cost of CoPS, but also results in reliability changing after it delivered to customer which greatly influences the operating cost in CoPS's lifecycle. However, the minimizing of two objectives is mutually conflicted. This paper presents a bi-objective LSS&CoPS model which considering operating stage of CoPS to balance the procurement cost and operating cost. Moreover, a hybridization of Pareto genetic algorithm (PGA) with multi-intersection and similarity crossover (MSC) strategy is proposed to solve the bi-objective problem. Also, a dual-chromosome is used to represent the variable-length chromosome. Finally, a cement equipment supplier optimal in a cement equipment enterprise is provided. Example indicates that the procurement cost and operating cost have been optimized, yields a Pareto optimal solution of supplier schema for project managers to make-decision and decrease the life cycle cost of CoPS. Additionally, the results show that the proposed approach is more preferably in Pareto optimal solution searching.

1. Introduction

Supplier selection has always been considered as a key factor within purchasing and supply management (Hsu & Hu, 2009; Luo, Wu, Rosenberg, & Barnes, 2009).The procurement of materials and components plays an important role in many respects for CoPS project, such as project approval and deliver, project schedule, project profitability and product service life (Aghai, Mollaverdi, & Sabbagh, 2014; Humphreys, Huang, Cadden, & McIvor, 2007). For technological system high in complexity and value, CoPS is produced as customized, one-off or small batched capital goods items and capital goods acquired through business-to-business (B2B) transactions, having higher unit costs than commodity products, which are often mass-produced (Hobday, 1998). The components of CoPS are typically tailor-made to suit the buyer's requirements, whereas commodity products generally consist of standardized or modular components (Dedehayir, Nokelainen, & Mäkinen, 2014). CoPS is likely to demonstrate complex component interfaces within a hierarchical system structure (Shibata, 2009), in contrast to commodity products, which tend toward simpler interfaces and a simpler architectural structure. The life cycle of CoPS is longer than commodity products (Dedehayir et al., 2014). Further, supplier selection occupied a core position in the life cycle of CoPS, so as to guarantee the reliability and service life of CoPS with lower cost (Sheikhalishahi & Torabi, 2014). In traditional procurement activities, procurement decision maker mainly influenced by the quoted price of different suppliers (Li, Murat, & Huang, 2009; Zhang & Zhang, 2011). Meanwhile, components quality is ensured by the initial qualified suppliers but not considering the influence of operating cost in the life cycle. For a CoPS, the complexity of components set a higher demand for supplier selection with less expensive cost and reliability requirements (Yu & Wong, 2015). Price-based purchase may lead to increase the operating cost of CoPS which has increased customer's unnecessary expenses and reduced the reputation of CoPS manufacturing enterprise (Wang, Xiao, & Yang, 2014). Currently, intelligent decision procurement with considering operating cost in life cycle is far more concern. Therefore, the existing problems in supplier selection for CoPS can be summarized into following aspects.

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(1) Price-based strategy. Price-based strategy tends to one-shot cooperation and not uses the historical transaction information of different suppliers effectively. It cannot be enhancing CoPS's quality. Choosing the lowest cost component is not benefit for decreasing the life cycle cost. Therefore, price-based purchase strategy cannot be guaranteed to reduce CoPS's cost in the whole life cycle.
(2) Limited considering phase. Traditional procurement is limited within CoPS manufacturing enterprise and not expanded to permeate in CoPS's life cycle. In addition, it only focused on procurement cost optimization for manufacturing enterprise but ignored the operating cost optimization for CoPS's life cycle.

In terms of the problems mentioned above, motivations of the research can be concluded as follows:

(1) Propose a multi-objective supplier selection model to handling the life cycle cost of CoPS in different phases.
(2) Develop techniques to solve the proposed supplier selection model, where the Pareto-optimal searching in supplier space is NP hard problem.

Therefore, the paper contributed a richer LSS&CoPS model, which considering procurement cost and operating cost in the life cycle. The model mainly focuses on supplier selection which simultaneously minimum procurement cost and operating cost when CoPS delivers to customer. Two objectives (procurement cost and operating cost) are mutually conflicted. Improving one objective will compromise another. For bi-objective optimization problem, it is desirable for Pareto optimal values to be evenly distributed in Pareto-optimal solution set, rather than converged in a single region of Pareto front (Wang, Guo, & Liu, 2013). Drawing upon this, it used Pareto optimal set to solve bi-objective optimization employing a hybridization of PGA and MSC strategy.

The remainder of this paper is organized as follows. In the next section, the relevant literature related to supplier selection of CoPS manufacturing is reviewed. Problem description and mathematic model of supplier optimal selection are developed in Section 3. Section 4 details the proposed hybridization of PGA with MSC strategy to approximate Pareto optimal solutions. A case study of supplier selection for cement equipment in a cement equipment enterprise is demonstrated in Section 5 and conclusions are given in Section 6.

2. Literature review

In recent years, many attempts have been published to develop and optimize supplier selection models. These studies encompass the wide scope of models ranged from simple linear single product deterministic problems to complex non-linear multi-product stochastic ones. Chai, Liu, and Ngai (2013) presented a general review of supplier selection models to support the development of richer supplier selection models.

Traditionally, the focus of supplier selection is usually on a deterministic model with single objective or multi-objective in supply chain management. For example, Latha Shankar, Basavarajappa, Kadadevaramath, and Chen (2013) used swarm intelligence based Multi-objective Hybrid Particle Swarm Optimization algorithm (MOHPSO) with non-dominated sorting method to achieve bi-objective optimization of minimizing total cost and maximizing fill rate in a supply chain design. Deng, Aydin, Kwong, and Huang (2014) investigated an integrated supplier selection model simultaneously considering suppliers of sourcing components in a product line. Wang and Li (2014) applied Nash bargaining game DEA model to consider the competition between suppliers with common weights comparing to traditional DEA method with various weights. Sheikhalishahi and Torabi (2014) addressed the maintenance supplier selection problem for a manufacturer to decide the purchasing of different replaceable parts for equipment's maintenance. Zeydan, Çolpan, and Çobanoğlu (2011) proposed an approach considers both qualitative and quantitative variables in evaluating performance for supplier selection to reduced product life cycle cost. Mahapatra, Das, and Narasimhan (2012) used a contingent theory for supplier management in product life cycle to choose optimal suppliers. Abdallah, Farhat, Diabat, and Kennedy (2012) established supplier estimation model of product life cycle cost from an environmental perspective. Liu and Hipel (2012) proposed a hierarchical decision model to select the optimal quality control strategies among various suppliers in producing a complex product. Aksoy and Öztürk (2011) used a neural network for selecting the most appropriate suppliers to solve the complex product configuration in JIT environment. Yeh and Chuang (2011) introduced green appraisal score into the framework of supplier selection criteria and used multi-objective genetic algorithm to find the Pareto-optimal solutions. Zhang et al. (2013) used a Pareto genetic algorithm to solve the green partner selection problem with green criteria of carbon emission and lead content in manufacturing production. Abdollahi, Arvan, and Razmi (2015) used an integrated approach of analytical network process (ANP) and data envelopment analysis (DEA) with considering product-related and organization-related characteristics to select lean and agile suppliers. Moncayo-Martínez and Recio (2014) proposed a Pareto-ant colony algorithm to minimize the cost of goods sold (CoGS) and the lead time (LT) in an assembly supply chain.

The use of uncertainty and risk in supplier selection models is a natural extension of a deterministic approach because all the model parameters, in practice, are not certain. This consideration results in the more realistic problems. In this matter, a number of researchers present comprehensive supplier selection models using stochastic and risk control approach. Wu, Wu, Zhang, and Olson (2013) developed a stochastic fuzzy multi-objective programming model for risk supplier selection in presence of both random uncertainty and fuzzy uncertainty. Bandyopadhyay and Bhattacharya (2013) proposed a modified NSGA-II with a fuzzy variable crossover algorithm to minimize the value of total cost and bullwhip effect in a bi-objective supplier selection problem. Kar (2014) proposed a group decision support approach for the supplier selection by integrating fuzzy AHP for group decision making. Lee, Cho, and Kim (2015) provided a decision support system to quantify the importance of the agility criterion for supplier selection. The proposed system used a fuzzy analytic hierarchy process (fuzzy AHP) and fuzzy technique for order of preference by similarity to ideal solution (fuzzy TOPSIS) to determine the weights of multi-criteria. Chai and Ngai (2014) proposed a soft decision model involving multiple stakeholders and multiple perspectives to perform theoretical decision modeling using interval and hesitant fuzzy methodology for strategic supplier selection in uncertain decision environments. Bilsel and Ravindran (2011) presented a multi-objective stochastic sequential supplier allocation model to help in supplier selection under uncertainty. Fallah-Tafti, Sahraeian, Tavakkoli-Moghaddam, and Moeinipour (2014) proposed a novel interactive possibilistic approach based on STEP method to minimize total costs, maximize suppliers' ranks and minimize total delivery time of products in closed-loop supply chain network design under uncertainty. Guo, Zhu, and Shi (2014) used a semi-fuzzy support vector domain description (semi-fuzzy SVDD) method to determine the select group of suppliers. Chen, Song, Liu, Fang, and He (2013) established the optimal cost-sharing model with Nash equilibrium and Stackelberg equilibrium to analyze cooperation status between the manufacturer and