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Using multi-objective genetic algorithm for partner selection in green supply chain problems

Wei-Chang Yeh *, Mei-Chi Chuang

Integration & Collaboration Laboratory, Department of Industrial Engineering and Engineering Management, National Tsing Hua University, P.O. Box 24-60, Hsinchu 300, Taiwan, ROC

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ABSTRACT

Partner selection is an important issue in the supply chain management. Since environment protection has been of concern to public in recent years, and the traditional supplier selection did not consider about this factor; therefore, this paper introduced green criteria into the framework of supplier selection criteria. The aim of this research was to develop an optimum mathematical planning model for green partner selection, which involved four objectives such as cost, time, product quality and green appraisal score. In order to solve these conflicting objectives, we adopted two multi-objective genetic algorithms to find the set of Pareto-optimal solutions, which utilized the weighted sum approach that can generate more number of solutions. In experimental analysis, we introduced a {4,4,4,4} supply chain network structure, and compared average number Pareto-optimal solutions and CPU times of two algorithms.

1. Introduction

In a broad sense, green supply chain refers to the management between suppliers, their products and environment, that is to say, the environment protection principle is brought into suppliers' management system. Its purpose is to add environment protection consciousness into original products and to improve competitive capacity in markets. The green supply chain known at present refers to supply chain effect brought about by green products proposed by European Community in the 21st century. Some companies, especially, small and medium enterprises, started to build cooperative corporations with supply chain partners, with the hope of promoting propagation of environment management initialization and designing new green products.

With increasing public awareness in environmental protection, enterprises began producing more green products than last decade. Deans (1999) pointed out, environmental protection was initiated by American industry, and environmental considerations became a significant factor to the procurement policy and selection of suppliers. WEEE and RoHS published by European Union in 2003 have exerted impact on the industries associated with electric and electronic equipment (EEE), since incompatible products are barred from the market of EU countries. Since environment protection was not taken into consideration in the traditional supply chain management, this paper introduced this concept to the green supplier selection mechanism which accords with the real situation.

The purpose of this paper was to construct an optimum mathematical planning model for defective supply chain system, and adopted two algorithms to solve this model, and obtained Pareto-optimal solutions for the supplier selection and product volume transportation problems. Four objectives were considered: (1) minimization of total cost comprised of product cost and transportation cost, (2) minimization of total time comprised of product time and transportation time, (3) maximization of average product quality, (4) maximization of green appraisal score. At last, the experimental study adopted two multi-objective genetic algorithms that were proposed by Murata, Ishibuchi, and Tanaka (1996) and Altiparmak, Gen, Lin, and Paksoy (2006) to solve the optimum mathematical planning model, and compared average number of Pareto-optimal solutions and CPU times of two algorithms to find the most efficient algorithm.

This paper is organized as follows: Section 2 is about literature review such as green supply chain management, green supplier selection criteria, WEEE/RoHS directives, defective supply chain system. Section 3 gives a problem statement and mathematical programming for supply chain. Section 4 gives a methodology. Section 5 gives computational results of three algorithms. Concluding remarks and future research are outlined in Section 6.

2. Literature review

2.1. Green supply chain management

Noci (1997) pointed out that companies should construct efficient management environment and emphasized on integrating the relationship between customers and suppliers. In fact,

* Corresponding author. Fax: +886 3 572 2204.
E-mail address: yeh@ieee.org (W.-C. Yeh).

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companies could produce green products together with suppliers as mutual cooperation relationship is developed. With this, companies could achieve the following effect: (1) reducing the amount of to-be-delivered accessories with low environment performance; (2) controlling the cost of suppliers' green products effectively; (3) decreasing the time responding to the market.

Sarkis (2003) advocated a policy and decision mechanism to assist administrators. The paper laid great stress on the components of green supply chain administration, and analyzed how these components became the basic elements of policy-making mechanism. The mechanism consisted of five strategies: products life cycle policy, enforcing policy on the environment influence on organization, efficiency demands of organization and green supply chain program.

Vachon and Klassen (2006) pointed out that through the interaction between suppliers and consumers, manufacturers could construct and practice an effective solution program, while facing the environment challenges. From the exploration of Canadian and American printing industries, they deduced that the partnership of green scheme with suppliers presented positive influence on delivery time, while the partnership of green scheme with consumers exerts positive influence on quality, flexibility and environment protection. Thereby, the partnership with consumers provided much greater benefit than the one with suppliers did.

Kainuma and Tawara (2006) stated that USA issued a practical handbook named *The Lean and Green Supply chain*, with the hope of calculating the achievement rate of financial improvement and environment protection, and briefly reviewing special instruments and methods. Through the handbook, companies constructed an assessment mechanism to observe lifecycle assessment, customer satisfaction and average inventory amount.

2.2. Green supplier selection criteria

In the traditional supply chain network, supplier selection criteria only consist of cost, time, and quality. However, environment protection issues were considered in the product process in the recent years, so enterprises hope that suppliers can produce products with environmental protection. Recently, researchers have developed a lot of supplier selection mechanisms which consider environmental protection issues in the following:

Noci (1997) suggested that green products suppliers selecting consisted of the following 3 steps: (1) finding out the applicable green strategies the companies can fulfill; (2) defining operation measure method to assess the performance of environment protection by the suppliers; (3) to select the most effective method to choose suppliers, to make sure that the suppliers could follow companies' strategies of environment protection.

Humphreys, Wong, and Chan (2003) held that traditional selecting process of suppliers only observed quality, flexibility and so on; however, with environment pressure increasing, many companies started to observe environment protection and assess environment performance of suppliers. Thereby, he advocated policy-drawing supporting instrument, to help companies' environment integrating principle enter the selecting process of suppliers.

Handfield, Steven, Sroufe, and Melnyk (2002) interviewed 500 subjects from different companies, who were also the experts of environment management, about the significance of environment performance index. The interviewees came from Mascotech, Cone Drive, IBM, Herman Miller, DLSC, Ford. Through the communication, he summarized the most important and the easiest ten supplier environment performance indexes to assess.

Noci (1997) provided a selection system of green product suppliers. At the beginning, the paper defined environment performance index of assessing suppliers, including quantitative and qualitative indexes. These indexes could be separated into 4 major types. First, companies should assess the environment efficiency of suppliers at present; second, companies should assess green capacity of suppliers; third, companies should consider green image of suppliers; lastly, companies should observe the performance process in economic view. Finally, the paper introduced two procurement programs, calculated the weigh of each attribute with AHP, and selected adequate stocking programs.

Handfield et al. (2002) introduced environment observation into stocking policies, and made policy-drawing process complex with quantitative and qualitative factors. However, a few companies performed analyzing with any random mechanism, and assessed suppliers by environment observation. The paper applied AHP as policy-drawing support mode and it further explained how AHP was used to assess relative significance in different environment peculiarity. Through Defier method, the 500 interviewers, from Mascotech, Cone Drive, IBM, Herman Miller, DLSC, Ford assessed the significance of environment performance index.

According to theories of Lamming, Noci, Azzone, Sarkisr, and Handfield, Humphreys et al. (2003) summarized the principles of selecting suppliers. He suggested a policy-drawing support instrument to help company environment integrating principles enter the selecting process of suppliers. The system, based on computers, integrated standard database of industry and applied Visual Basic as its principal built environment. The cases including 8 suppliers were introduced to make quantitative assessment and then qualitative assessment. The quantitative assessment used multi-attribute analysis technique, MAA, while qualitative assessment applied a series of questionnaires.

2.3. WEEE and RoHS directives

Manufacturing of electric and electronic equipment, EEE is one of the industries developing rapidest over the world. Simultaneously, with technique innovated and market of electric and electronic equipment, EEE expanded, the replacement of old equipments is speeded up, leading to apparent increasing of waste electric and electronic equipment, WEEE and arousing new environment challenges. In 1998, Western Europe witnessed 6 million tons of electric and electronic equipment, WEEE, and the increasing amount of electric and electronic equipment WEEE would at least reach 3–5% each year (EC). In 2004, over 3 billion computers would reach their using lifespan in America.

From home appliances to computers, electric and electronic equipment, EEE covers vast range. Materials and accessories of waste electric and electronic equipment, WEEE are different and complex. Many materials are strongly toxic, such as bromide, toxic alloy, sensitive substance and plastic products. If these substances are not treated adequately, waste electric and electronic equipment, WEEE will cause serious environment pollution.

From environment pollution caused by waste electric and electronic equipment, WEEE, companies should build management system for waste electric and electronic equipment, WEEE to prolong the lifecycle of electric and electronic equipment, EEE. The management system contained collecting, classifying and so on, and included five common treating strategies (Rose, 2000; Rose, Beiter, & Ishii, 1999):

(1) Reusing: to obtain the used products and their related accessories.
(2) Repairing: to prolong usage term through repair and maintenance.
(3) Reproducing: to detach certain accessories from waste products for future usage.
(4) Recycling: to treat used products or their accessories, to reprocess the materials, and to replace the required new materials when producing new products.
(5) Disposing: incinerating or burying.