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A genetic algorithm for supply chain configuration with new product development

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ABSTRACT

New product development has become increasingly important recently due to highly competitive market place and economic reasons. Development and production of new products in the planning horizon require an efficient and responsiveness supply chain network. As new products appear in the market, the old products could become obsolete, and then phased out. A generously persuasive parameter for new product and developed product problems in a supply chain is the time which the developed products are introduced and the old products are phased out and also the time new products are introduced in the planning horizon in order to maximum the total profit.

With consideration of the factors noted above, this study proposes to design a multi echelon multi product multi period supply chain model which incorporates product development and new product production and their effects on supply chain configuration.

In terms of the solution technique, to overcome NP-hardness of the proposed model, priority based genetic algorithm is applied to find the suitable time for introducing developed and new product in the planning horizon, production schedule and design of supply chain network in order to maximum the total profit in a reasonable computational time. The accuracy of the proposed genetic algorithm is validated on small, medium and large instances that have been solved using the software LINGO, in order to evaluate the performance of the algorithm. Then, the implementation of the fuzzy crossover and mutation controllers is described. It is able to regulate the rates of crossover and mutation operators during the search process. Finally, a comparison is done on conventional GA and the controlled GA.

1. Introduction and literature review

In a Supply Chain (SC), the product flow starts with suppliers and manufactures, and then final products are delivered by distributors to the customer groups to meet their demands.

As customer tastes are rapidly changing, to survive in a highly competitive industry, strategies to collaborate with or compete with suitable firms within a network should be considered in the New Product Development (NPD) process. To overcome these challenges, integration of the NPD process and the SC can offer a sustainable competitive advantage to achieve success according to the current competitive environment in the market place. While both of the NPD process and SC problems separately have received a considerable attention in the literature, there is little (or no) effort in the literature for covering SC and NPD in which there are several products produced. Since most SC networks have multiple echelons, periods and products, the SC network problem is an NP-complete problem (Ibaraki & Katoh, 1988). These cause the search space and time required to obtain a solution to increase markedly.

The main focus of this research is on the integration of NPD and SC and its network design problem and then the priority based Genetic Algorithm (GA) is proposed to solve large size problem. In the following subsections related literature is discussed.

1.1. Integration of NPD and SC

Manufacturers are trying to introduce new products to the market quickly. Having an efficient and effective SC network prepares a marketing area for enterprises in the global market environment. A SC network is typically composed of suppliers, manufacturers, distributors and customer groups.

The NPD process starts with having ideas about new products. Multiple sources, including customers, top management,

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employees, competitors and new technologies can be used for generating new ideas. As noted by Van Kleef, Van Trijp, and Luning (2005) a range of methods is available that can aid the product developer in generating new product ideas based on input from marketing research. There are many researches that focus on the critical factors of successful NPD process, for instance integration is recognized as one of the critical enablers and researchers concentrated on each aspect of SC integration (Flynn, Huo, & Zhao, 2010; Hong, Doll, Nahm, & Li, 2004; Koufteros, Edwin, & Lai, 2007). As another study, He, Lai, Sun, and Chen (2014) stated the combination of two important integrations as supplier and customer integrations together and examined their impacts on new product performance.

In addition to critical factors, SCs through which new products are manufactured need flexibility and responsiveness elements. Each element of a SC echelons may have options which is able to satisfy a required function as the procurement, transportation and producing a product. These decisions after a new product design is complete get more importance because it increases the costs (Simchi-Levi, Kaminsky, & Simchi-Levi, 2000).

As new products appear in the market, the old products could become obsolete, and then phased out. A generously persuasive parameter for NPD problems in a SC is the strategy of introduction a new product and phasing out the old products which are developed in the planning horizon. Before launching a new product, a manufacturer must decide the timing of the product launch and the production/sales plan over the planning horizon. According to Billington, Lee, and Tang (1998) there is two rollover strategies namely single product roll and dual product roll to introduce new products to the market. In the first strategy, single product roll, the time phasing out the old product and the time introducing the new product are the same which means that as the new product is introduced the old product is phased out. As such, in dual rollover strategy as the new product is introduced the firm continues producing the old product, in other words, the coexistence of both products is allowed during a certain period of time. In the proposed model the single product rollover is assumed.

Although many studies have investigated the SC configuration and the NPD problems separately, a few researchers have dealt with SC together with NPD. Naraharisetti and Karimi (2010) proposed the SC redesign and new process introduction in multipurpose plants. They added some production and inventory facilities, distribution and customer centers to their chain. An integrated optimization model for configuring the SC of new product is developed by Amini and Li (2011). Their work was a first attempt to model the interaction between new product diffusion and SC configuration. The aim of their research is configuration of SC subject to demand dynamics and other SC parameters such as lead-time and inventory. Also, Li and Amini (2012) developed an integrated optimization model which allowed multiple-sourcing and safety stock placement decisions in coordinate with the demand dynamics during the new product diffusion process throughout its life cycle. As another study, Nepal, Monplaisir, and Famuyiwa (2011) has extended a multi-objective optimization model for SC configuration during product development. Their presented model consists of two objectives: maximization of the total compatibility index in strategic alliance and minimization of the total SC costs. Their model improves SC efficiency and stability by jointly considering sourcing, inventory costs and compatibility decisions during the configuration of the SC. They solved their model by using GA. Jafarian and Bashiri (2014) provided a five echelon dynamic SC model. Their proposed model considers the time of new product lunching in the SC, which is optimized with SC configuration simultaneously. In addition, production, sales, transportation planning and their lead times are considered in the model. In their proposed model each firm individually decide to introduce new products and their model considers developing a single product.

To improve NPD activities in a SC, this paper presents an integer linear programming model that considers a multi echelon multi product multi period SC together with NPD. It generalizes the previous studies in the following aspects:

- The previous studies have assumed single product models. They considered the SC for producing only one product and the product is developed during the planning horizon. This study proposes a multi product model.
- The proposed model includes three groups of products. Products which are being produced by the company, products that are developed during the planning horizon and products which is decided to newly be produced during the planning horizon.

1.2. Genetic algorithm

Many SC optimization models are NP-hard and researchers employ heuristics or meta-heuristic methods to find the optimal solution for them. As effective approaches for solving different problems from manufacturing systems, SC systems, transportation systems and logistics systems, heuristics or meta-heuristic methods have drawn more attention from researchers in recent years (Ahmadizar, Zeynivand, & Arkat, 2015; Bandyopadhyay & Bhattachary, 2014; Bootaki, Mahdavi, & Paydar, 2014; Fahimnia, Luong, & Marian, 2012; Kumar & Chatterjee, 2013; Mahdavi, Paydar, Solimanpur, & Heidarzade, 2009; Paydar, Mahdavi, Sharafuddin, & Solimanpur, 2010; Ribas & Companys, 2015; Sel & Bilgen, 2014).

He, Huang, and Chang (2015) formulated a mixed integer programming model for the multi echelon container SC network where the objective is subject to the minimization of the total SC service cost. They proposed a novel simulation-based heuristic method for solving it. As another study, Jamshidi, Fatemi Ghomi, and Karimi (2015) proposed a mixed integer non-linear model for a five-tier SC with controllable lead time and multiple transportation options and developed a novel meta-heuristic method that combines the Taguchi's feature with Artificial Immune System to solve their proposed model. They examined the performance of the proposed solution method against a set of numeric instances. Soleimani and Kannan (2015) developed a deterministic multi echelon, multi product, multi period model for a closed-loop SC network and presented a new PSO-GA hybrid algorithm to solve various kinds of problems. Then a complete computational analysis was under taken to validate their proposed algorithm.

GAs, which are search techniques that mimic the process of natural selection and natural genetics, have been routinely used to generate useful solutions for optimization and search problems. It belongs to the class of meta-heuristic optimization techniques.

GA can be implemented in several different ways to solve different problems. One of the important issues that affect the performance of GAs is representation. Different genetic representations are introduced for different problems.

Syarif, Yun, and Gen (2002) have developed a spanning tree-based GA approach for the multi source, single product and multi stage SC network design based on Prüfer numbers.

A priority-based GA was developed by Gen, Altiparmak, and Lin (2006), in which new decoding and encoding procedures were used to adapt to the characteristic of a two-stage transportation problem. The aim of their proposed model was minimizing the total logistic cost including the opening costs of distribution centers and shipping cost from plants to distribution centers and from distribution centers to customers. Lin, Gen, and Wang (2009) formulated an integrated multi stage logistics network model with considering the direct shipment and direct delivery of logistics