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Heuristic genetic algorithm for capacitated production planning problems with batch processing and remanufacturing

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Abstract

In this paper, we analyze a version of the capacitated dynamic lot-sizing problem with substitutions and return products. Both batch manufacturing and batch remanufacturing are considered within the framework of deterministic time-varying demands in a finite time horizon, where the option of emergency procurement/outsourcing subject to a subcontract is also allowed. Setup costs are taken into account when batch manufacturing or batch remanufacturing takes place. We first apply a genetic algorithm to determine all periods requiring setups for batch manufacturing and batch remanufacturing, then develop a dynamic programming approach to provide the optimal solution to determine how many new products are manufactured or return products are remanufactured in each of these periods. The objective is to minimize the total cost, including batch manufacturing, batch remanufacturing, emergency procurement, holding and setup costs. Numerical examples illustrate the effectiveness of the approach.

Keywords: Dynamic lot-sizing; Inventory; Product substitution; Remanufacturing; Genetic algorithms

1. Introduction

Due to both economic incentives and legal pressures, more and more companies engage in the product recovery business, which entails activities to regain materials and value adding in return products. A very important field of product recovery is remanufacturing. It involves activities that make remanufactured products or major modules be marketable again and potentially as good as new. This is a widespread phenomenon for high-valued industrial products like copiers, computers, vehicle engines or medical equipment.

The traditional models of production planning and inventory control (see Orlicky, 1975) usually do not take into account the multiple uses of products. Only recently research has been started to integrate so-called product recovery management into production planning systems (see Schrady, 1969; Richter, 1997; Richter and Sombrutzki, 2000; Richter and Weber, 2001; Beltran and Krass, 2002) as one of the approaches of an ecologically oriented production management. These approaches endeavor to model product recovery management activities under several assumptions including, in

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particular, the assumption of deterministic demands.

Although some underlying assumptions, in particular, deterministic demand and finite-horizon, are quite restrictive, the model has seen numerous applications in a variety of areas in operations management. These range from production planning/inventory control settings to capacity expansion problems (Luss, 1982), product assortment, batch queuing, investment-consumption and reservoir-control problems (Veinott, 1969). The deterministic models can primarily be subdivided into static and dynamic models. The former corresponds to the classical economic order quantity (EOQ) seeking an optimal tradeoff between fixed setup and variable holding costs. Several authors have proposed extensions to this model that take return flows into account. A first model of this type has been proposed by Schrady (1969). Mabini et al. (1992) have extended the model to multi-item system where all items share a common repair facility. Subsequently, Richter (1994) considered Schrady's model for alternating procurement and recovery batches. Richter (1996, 1997) extended the analysis to multiple consecutive procurement and recovery batches. Furthermore, Teunter (2001) considered the same model for a modified disposal policy. Rather than assuming a constant disposal rate, he assumed all returns that occur during a certain time span are disposed. Expressions for the optimal lot-sizing are derived under this policy.

Besides the above static models, several dynamic lot-sizing models similar to the classical Wagner and Whitin (1958) one have been proposed in the reverse logistics context. Richter and Sombrutzki (2000) discussed applicability of the original Wagner/Whitin model in reverse logistics situations. By reversing the time axis they showed that the traditional model could be interpreted as looking for optimal recovery batches for accumulating return products. Note that this interpretation includes neither an alternative procurement option nor disposal.

Beltran and Krass (2002) considered a dynamic lot-sizing problem for an inventory point facing both demand and returns. This transpires to the original Wagner/Whitin model with the exception that (net) demand may be positive or negative. Moreover, the inventory may both be raised by procurement and be decreased by disposal. The authors have shown that the zero-inventory-production property, which is well known for the original model, needs to be modified. A procurement order may sometimes be delayed beyond the first occurrence of inventory depletion due to returns. The authors have proposed a dynamic programming approach in the general case.

Demand substitution in inventory management is envisaged in a variety of contexts for traditional production planning. Most papers concentrate mainly on the problem in a single period. A detailed literature review can be found in Smith and Agrawal (2000). Balakrishnan and Geunes (2000) considered a requirement planning problem with substitutions in a multi-period horizon. A dynamic programming method was derived to find the production and substitution quantities that satisfy given multi-period downstream demands at a minimum total setup, production, conversion and holding cost. However, few authors, except Inderfurth, considered the production planning problem with consideration of remanufacturing and product substitution at the same time. Inderfurth (2003) has derived optimal policies for hybrid manufacturing/remanufacturing systems with product substitution. A new product is offered in place of a remanufactured one when there is a remanufactured product shortage. In Li et al. (2006), we analyzed a version of the dynamic lot-sizing model with substitution and return products. A dynamic programming approach has been proposed to derive the optimal solution in the case of a large quantity of return products. Then a heuristic approach for the general problem has been presented to determine feasible production plans.

In this paper, we deal with a multi-period production planning problem with return products under substitution and capacity constraints. Product demands should be fulfilled either by manufacturing new products or by remanufacturing the products returned from customers in batches. Otherwise, emergency procurement/outsourcing subject to a subcontract is adopted to meet the unfulfilled demands when needed. A substitution takes place whenever the demand for a type of product is met using stocks of another product type. Although various substitution structures arise in real life, our study focuses on downward substitution where product i can be substituted by product j, but not vice versa. Downward substitution happens, for instance, in a semiconductor industry producing similar integrated circuits with varying performance characteristics, where circuits with higher-performance characteristics (such as,