Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 15 (2011) 5170 – 5178

Procedia Engineering

www.elsevier.com/locate/procedia

Advanced in Control Engineeringand Information Science

A single-Item uncapacitated lot-sizing problem with remanufacturing and outsourcing

Nengmin WANG*[a,b];Zhengwen He [a,b];Jingchun SUN [a,b] ;Haiyan Xie [c];Wei Shi [c]

a.Management School of Xi'an JiaoTong University, 710049,NO.28 Xiannin Road Xian Shaanxi China

b.The key lab of the ministry of education for process control& efficiency engineering, 710049,NO.28 Xiannin Road Xian Shaanxi China

c College of Engineering and Information Technology, University of Arkansas at Little Rock, 2801S. University Ave. ETAS 202, Little Rock, Arkansas, 72204 USA

Abstract

This paper addresses the single-item, dynamic lot-sizing problem for systems with remanufacturing and outsourcing. Therein, demand and return amounts are deterministic over a finite planning horizon. Demand may be satisfied by the manufacturing of new items, remanufactured items, or outsourcing, but it cannot be backlogged. The objective of this study is to determine the lot sizes for manufacturing, remanufacturing, and outsourcing that minimise the total cost, which consists of the holding costs for returns and manufactured/remanufactured products, setup costs, and outsourcing costs. The problems addressed in this paper are an extension of those addressed by Richter et al. (2000,and 2001), Teunter et al. (2006), and Aksen et al. (2003). In this paper, the separate setup costs scheme is considered, we propose a dynamic programming approach to derive the optimal solution in the case of large quantities of returned product. The complexity of this dynamic programming approach is $O(T^2)$, wherein T is the number of periods in the planning horizon.

Keywords: Lot sizing; remanufacturing; outsource; dynamic programming

1.Introduction

Economic incentives, legal pressure, and societal pressure have motivated an increasing number of companies to engage in the product recovery business, which refers to activities that aim to regain materials and added value in used or returned products (Thorn and Rogerson 2002)[1]. A key component of product recovery is remanufacturing, which can be defined as the recovery of returned or used products and often involves disassembly, cleaning, testing, part replacement/repair and reassembly operations. The remanufactured items are as-good-as new items. Remanufacturing is of great social concern in many industries, such as single use cameras, machine tools, automobile engines, and computers. At the same

* Corresponding author. Tel.:+8613669132029

E-mail address: nengmin.wang@163.com

1877-7058 © 2011 Published by Elsevier Ltd.
doi:10.1016/j.proeng.2011.08.959

time, remanufacturing can be profitable. For example, Volvo has established operations for the salvaging and dismantling of cars, which have led to the generation of revenue. In addition, Canon and Xerox remanufacture products that are worn out or obsolete, which is now more profitable than manufacturing new products (Stock et al. 2000)[2]. The Yuchai group is the first and largest conglomerate to remanufacture automobile engines in China. Remanufacturing development in the Yuchai group has not only secured significant economic benefits but has also resulted in good social and ecological benefits via the generation of 500 million Yuan in economic returns in 2006, reduced industrial pollutant emissions, and saved resources.

Our study is an extension of the problems that were addressed by Richter et al. (2000 and 2001) [3][4]and Teunter et al. (2006)[5], which include single-item lot sizing with manufacturing but without outsourcing. Our model differs from those that investigate lot sizing with outsourcing, because our model considers remanufacturing. This paper addresses the single-item, dynamic lot-sizing problem for systems with remanufacturing and outsourcing. Demand and return amounts are deterministic over a finite planning horizon. Demand may be satisfied by the manufacture of new items, remanufactured items, or outsourcing but cannot be backlogged. The objective of this study is to determine the lot sizes for manufacturing, remanufacturing, and outsourcing that minimise the total costs, which consist of the holding costs for returns and manufactured/remanufactured products, setup costs, and outsourcing costs. For the lot-sizing problem with remanufacturing, Van den Heuvel[6] has demonstrated that the problem becomes NP-hard when variable (re)manufacturing costs are included, even under the condition that the variable cost for manufacturing is larger than that for remanufacturing (which will typically hold if remanufacturing is economically motivated). Therefore, problems that include remanufacturing and outsourcing will be more complex, and only some specific problems can be solved in polynomial time. In this paper, t separate setup costs scheme is considered, we propose a dynamic programming approach to derive the optimal solution in the case of large quantities of returned product. The complexity of the proposed approach is $O(T^2)$, wherein T is the number of periods in the planning horizon.

This paper contributes by: (1) developing an optimisation model in order to simultaneously address several critical issues in production planning, including single-item, multi-period, remanufacturing, and outsourcing and (2) establishing the characteristics of single-item lot sizing with remanufacturing and outsourcing and developing a polynomial algorithm for the model. The rest of this paper is organised as follows. In section 2, we develop an uncapacitated, production-planning model that includes remanufacturing and outsourcing for a multi-period, single-item problem with separate setup costs. In this case, there are dedicated production lines for manufacturing and remanufacturing. In section 3, we propose a dynamic programming approach to derive the optimal solution when there are large quantities of returned products. In section 4, we provide a short conclusion and suggest future research.

2. The Mathematical Model

Assume that the number of planning periods that is under consideration is T. The length of each period may be a week or a month, depending on the application. Let T = {1, 2 …, T} be the index set of periods. The demand D_t of a product in each period t($t \in$ T) is satisfied by new products, remanufactured products, or outsourcing. Products that are manufactured and remanufactured are both regarded as serviceable products, which are undistinguishable in terms of functionalities and quality. The proposed model is referred to as the single-item, uncapacitated lot-sizing problem with remanufacturing and outsourcing (SULPRO) model. The given conditions include the product demand in every period and the unit costs for manufacturing, remanufacturing, outsourcing, and setup. The SULPRO model seeks to determine the quantities for manufacturing, remanufacturing, and outsourcing and the stock level of each product in each period while meeting all demands at a minimum total cost.

The following are the definitions of the sets, parameters, and variables of the SULPRO model:

Sets: