Available online at www.sciencedirect.com
ScienceDirect
Int. J. Production Economics 109 (2007) 185–194
international journal of production economics
www.elsevier.com/locate/ijpe

Setting the holding cost rates in a two-product system with remanufacturing

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Received 6 July 2006; accepted 12 December 2006
Available online 11 January 2007

Abstract

This paper analyzes a two-product system with joint manufacturing and remanufacturing. In such a system the end-product stock contains both manufactured and remanufactured products, while the remanufacturable stock may contain products of different quality. Due to its complex structure, the valuation of inventories at the various stocking points is ambiguous. For two cases regarding quality differentiation we determine holding cost rates such that the outcomes of a net present value approach and an average cost approach are approximately equivalent. We show how the correct holding cost rates deviate from traditional valuation methodology and demonstrate its impact on operational performance.

Keywords: Reverse logistics; Remanufacturing; Net present value; Holding cost; Inventory management

1. Introduction

The management and control of inventory systems with joint manufacturing and remanufacturing has received considerable attention in recent literature. Research has focused on optimal policy structures (e.g. Inderfurth, 1997; Fleischmann et al., 2002), heuristic policy structures (van der Laan et al., 1999; Toktay et al., 2000; Inderfurth and van der Laan, 2001; Kiesmüller, 2003; Mahadevan et al., 2003; Teunter et al., 2004), and heuristics to calculate near optimal parameter values (Kiesmüller and Minner, 2003; van der Laan and Teunter, 2005).

In most of these models, the stocks considered are returned items that are not yet remanufactured and serviceable stock that consists of both manufactured and remanufactured items. The setting of holding cost rates of these stocks is an important determinant for the performance of inventory policies in a reverse logistics environment as was shown by Teunter et al. (2000) in a simulation study. It appeared that an intuitive choice of the holding cost rates easily leads to very poor decisions and system performance. In contrast to using simulation to test some intuitive alternatives in Teunter et al. (2000), in van der Laan (2003) the author uses an exact mathematical analysis to show that the commonly used valuation method is not valid. Teunter (2001) applies the findings of Teunter et al. (2000) in a disassembly environment via a simulation study. The findings are in line with previous works, e.g. using a straightforward application of the

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0925-5273/$ - see front matter
doi:10.1016/j.ijpe.2006.12.049

traditional valuation methods in a reverse logistics system can be a costly mistake.

The problem with respect to holding cost rates in an average cost (AC) framework arises because the AC approach does not *explicitly* take into account the time value of money. The opportunity cost of inventory investment is usually included in the holding cost parameters. The assumption behind this is that the opportunity cost is (approximately) linear in the capital tied up in inventory and the opportunity cost rate. This assumption was validated, using a net present value (NPV) framework, for the EOQ model (Hadley, 1964; Trippi and Lewin, 1974; Thompson, 1995; Hofmann, 1998; Klein Haneveld and Teunter, 1998), but the conclusion is less clear for multi-echelon systems (Grubbström and Thorstenson, 1986) and remanufacturing systems (Teunter et al., 2000; van der Laan, 2003). The NPV, or discounted cash flow approach is generally considered to be the right approach in financial decision making, since it focuses directly on cash flows rather than derivative costs and profits. However, due to a simpler structure, the AC approach is more frequently employed.

In this paper we analyze a two-product system with joint manufacturing and remanufacturing. For such a system, complications in finding the correct holding cost parameters arise because of two reasons. Firstly, the convergent structure of multiple sources (manufacturing and remanufacturing) means that serviceable inventory contains items that are physically and qualitatively the same, but are produced against different costs. For example, Thierry et al. (1995) report that a copier manufacturer handles the recovery operations in house whereas all parts fabrication activities are outsourced. Therefore, at a parts level, inventory is replenished both from in-house remanufacturing and outside procurement.

Secondly, the divergent structure of using returned products for two different end-items means that recoverable inventory contains products that may be qualitatively different, but exactly the same in terms of inventory investment. Again in the context of copier remanufacturing Thierry et al. (1995) report that, in remanufacturing operations addition of new technology by replacing (upgrading) parts and/or by adding new software to change the product functionality is carried out. Modular design of copiers also enables such flexibilities. This flexibility essentially means that potentially a part (module) can be upgraded to various types or qualities according to need, depending on marketing conditions and legislative constraints.

In the first case, routinely used valuation methods such as activity based costing (ABC), tell us to differentiate between the two items and set separate holding cost rates since the capital tied up in inventory differs. In the second case, traditional valuation methodology tells us to *not* differentiate between these items as the capital tied up in inventory is the same. Our analysis shows that, in this setting, the above methodology is fundamentally wrong on both accounts.

The remainder of the paper is organized as follows. After introducing the system in the next section, we analyze two cases (incoming and outgoing quality differentiation) under the NPV and AC approach and try to find holding cost rates such that the AC approach is equivalent to an NPV analysis. Then in the following section, we demonstrate the effects of traditional valuation methodology on the remanufacturing operation dynamics by comparing that approach to the theoretical results of our analysis. Finally, we discuss the main results and point out the managerial implications.

2. Model development and analysis

We consider a two-product, joint manufacturing and remanufacturing environment as depicted in Fig. 1. Customer demand for end-products A and B can be satisfied by newly manufactured products and by remanufacturing of used products. The returned products, denoted remanufacturables, are collected in a common stocking point. These products can be either processed by remanufacturing process A, which will turn them into type A products, or by remanufacturing process B, which will turn them into type B products. The type of conversion is either dictated by the incoming quality of remanufacturables (Case 1) or a decision on the desired outgoing quality (Case 2). All demand and return rates (number of products per time unit) are constant and deterministic. We assume that for each product type the product recovery rate (the long-run number of products recovered per time unit) is smaller than the demand rate, so to satisfy demand we also need the manufacturing process to replenish the stock of end-products (denoted ‘serviceables’). All remanufacturables are eventually used for either product A or B, that is, there is no disposal after the