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Green-component life-cycle value on design and reverse manufacturing in semi-closed supply chain

Chun-Jen Chung[b], Hui-Ming Wee[a,*]

[a]Department of Industrial Engineering, Chung Yuan Christian University, Chungli 32023, Taiwan, ROC

[b]Department of Business Administration, Meiho Institute of Technology, 23, Ping Kuang Road, Neipu, Pingtung 912, Taiwan, ROC

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Abstract

Due to increasing competitive pressure, shortened life cycle and environmental consciousness, more attentions have been paid to resource usage reduction and ecology protection. Green product design has received much attention recently, because product design significantly influences the cost of disassembly, component inspection and repair, remanufacturing and recycling. We investigate the impact of the green product design, the new technology evolution and remanufacturing on the production-inventory policy, and develop an integrated deteriorating inventory model with green-component life-cycle value design and remanufacturing. We provide time-weighted inventory (TWI) approach to analyze the saw-tooth inventory for the replenishment policy of the integrated production-inventory deteriorating model. A numerical example is also presented to illustrate the theory. The results show that the new technology evolution, take-back ratio and the system's holding costs are the critical factors affecting the decision-making in a green supply chain inventory control.

Keywords: Integrated deteriorating model; JIT delivery; Production and inventory; Green-component life-cycle value design; Reverse manufacturing

1. Introduction

Products with short life cycles are important sources of enterprises profits. Such products include high-fashion content and technological new products. Due to increasing competitive pressure, shortened life cycle and environmental consciousness, collaboration and smart use of resources in supply chain process are becoming more important. The main activities related to the above issues consist of information, resources and relevant technique sharing, and the utilization of the reverse manufacturing activities and techniques. Green supply chain and system collaboration decisions have become the current issues faced by organizations with strong internal and external linkages.

Due to environmental and ecological responsibility, enterprises are trying to reuse, remanufacture and recycle the used products to reduce the negative impact on environment, especially the manufacturers of the electrical consumer products. Therefore, the reverse manufacturing problem, which is strongly related to all stages of a product development, nowadays is a critical problem to all levels of the electrical and computer industry. This paper considers and simplifies the reverse manufacturing

*Corresponding author. Tel.: +886 3 456 6142;
fax: +886 3 456 3171/4499.

E-mail addresses: cjchungboy@gmail.com (C.-J. Chung), weehm@cycu.edu.tw (H.-M. Wee).

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problem from the electrical industry. The goal of this paper is to develop a production-inventory policy considering green-component life-cycle value design, the new technology evolution and remanufacturing. The optimal inventory system is developed to comprehend the importance of related factors in the policy and to find the influence of cost components in a semi-close green supply chain. A short life-cycle product with a stationary demand is considered.

Several countries at all levels are developing waste handling prohibitions, regulations or incentive programs to encourage alternative disposition of electronic waste (Callahan et al., 1997). Such policies ensure the producer and the consumer greater responsibility for the safe disposition of their products (Boks et al., 1998). These explain why, in recent years, the rate of electronic reuse and recycling has steadily increased, and why in America the volume of products recovered is expected to increase at an annual rate of 18% (National Safety Council's Environmental Health Center, 1999). Governments have begun implementing regulations that impose various requirements on manufacturers with respect to their end-of-life (EOL) products. Such regulations seek to reduce both the volume and toxicity of waste by increasing incentives for manufacturers to fully incorporate EOL concerns into product design (Fishbein, 2000; Toffel, 2002).

Green product design has received numerous attentions recently. Product design changes can significantly influence the cost of disassembly, component inspection and repair, remanufacturing and recycling the reusable materials. Owing to some regulations and international proposals, such as European Union's proposal for a directive on Waste Electrical and Electronic Equipment (WEEE), some manufacturers seeking to reduce product recovery and remanufacturing costs have begun modifying product designs and incorporate EOL product reuse concept into product and component design (Toffel, 2002).

Life-cycle design seeks to maximize the life-cycle value of a product at the early stages of design, while minimizing cost and environmental impact. Ishii et al. (1994) introduced the concept of the life-cycle value and illustrated a prototype computer tool for Design for Product Retirement (DFPR) using an example from the computer industry. The paper focused on product retirement and advanced planning for material recycling. DFPR was applied to retirement strategies for product disassembly and reprocessing of subassemblies and components. For the issue of designing for remanufacturing or recycling, Klausne and Wolfgang (1999) outlined a concept for the integration of product repair and product take-back. They showed that the replacement of a large share of conventional repairs with remanufacturing and reconditioning would result in a higher service level in product repair, and a significantly improved financial performance in both product take-back and product repair for a variety of electromechanical and electronic products. Matching the current exponential growth rate in electronic device, integration capabilities with design productivity are a problem known as the design productivity gap. This gap cannot be filled solely by incremental improvements in conventional design techniques. Component reuse is one of the new design techniques to increase design productivity (Wetenschappen et al., 2002). However, considering technical evolution of component design, few researches considered the convertibility of a take-back product having a new function.

In determining the optimal lot sizes for production/procurement and recovery, Schrady (1967) was the first author to study the problem. He analyzed the problem in the traditional Economic Order Quantity (EOQ) setting: deterministic and continuous demand and return. Nahmias and Rivera (1979) studied an EOQ variant of Schrady's model with a finite recovery rate. They assumed that the recovery rate was larger than the demand rate, and derived a lot-sizing formula. Koh et al. (2002) also assumed infinite production rate and the finite recovery rate. Their study is more general that that of Nahmias and Rivera (1979), since they allow the recovery rate to be both smaller and larger than the demand rate. Kiesmüller (2003) assumed that demands are satisfied from serviceable inventory, which can be replenished by remanufactured returned items, which are as good as new, or by new produced items. White et al. (2003) presented a generalized overview of product recovery. The purpose of their paper described the recovery of computers as a step-by-step process, and framed an environmental research agenda for recovery management of computer industry. Bonney et al. (2003) examined some of the changes that are occurring in manufacturing companies and in the market. Changes include the product design process, reduction in product design time, new technology, new materials and production methods, the availability of better quality data, organization change including changes in techniques and tools used for