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A hybrid simulation optimization method for production planning of dedicated remanufacturing

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ABSTRACT

This paper presents a hybrid cell evaluated genetic algorithm (CEGA) for optimization of the dedicated remanufacturing system with simulation. The paper first summarizes the special characteristics and problems of the dedicated remanufacturing. The paper then proposes a simulation model with a prioritized stochastic batch arrival mechanism, considering factors that affect the total profit. Based on the simulation model, the CEGA algorithm is developed to optimize the production planning and control policies for dedicated remanufacturing. A case study is provided based on the remanufacturing facility located at Austin, USA

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1. Introduction

Product remanufacturing develops rapidly in recent decades due to intensified environmental legislations and economic concerns. Through remanufacturing, products/components that would otherwise head to land-fill or incineration will instead go through a set of value and material recapturing processes, including distribution, inspection, disassembly, repair, redistribution, and remarketing or recycling. Remanufacturing allows for reusable components and recoverable materials reenter the supply chain for future reuse or new product fabrication (Zhang et al., 2004).

Remanufacturing is generally conducted under two different business strategies: the combined model and the dedicated model. Most remanufacturing operations in European countries employ the combined model. Under this strategy, remanufacturing is done by the original manufacturer combined with its forward production. Remanufacturing in the North America usually adopts a dedicated model, in which remanufacturing is outsourced to dedicated third-party remanufacturers (Patel, 2006). There are a growing number of examples of the dedicated model in the electronics industry. Original equipment manufacturers, such as Dell, Hewlett-Packard, and IBM, retail stores such as CompUSA and Best Buy have outsourced their remanufacturing operations to third-party providers including Noranda Recycling, Image Microsystems, Genco, and among others. The driving force behind this trend lies in the dramatically increased volume, complicated return patterns, and the increasingly complicated material contents of the consumer electronic products. OEMs are no longer capable of processing the huge volume of the returned post consumer products effectively and efficiently with their own facilities. The advantages associated with the dedicated outsourcing model also include: third parties are dedicated and, therefore, are more resourceful and efficient in collection and recovery of returned products; third party providers have more expertise in product recovery processes that result in waste minimization and full potential recovery of returned products; because third party providers are outside companies, there is no interference with the original manufacturer's production line, thus simplifying the operations.

Despite the increased application of the dedicated model in remanufacturing, hardly any theoretical and

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applied research efforts are directed to the problems associated. Most current research efforts are focused on the combined model (Thierry et al., 1995; Connelly and Koshland, 1997; Ayres et al., 1997; Ferrer and Guide, 2002; White et al., 2003). As for the dedicated model, such research results cannot be applied directly. Intended to fill the gap, this paper presents a study conducted on the dedicated model with batch and prioritized product return. Based on a remanufacturing facility located in Austin, TX, this paper first provides an in-depth analysis of the dedicated model regarding its material flow, production process, and the problems associated. Targeting on these problems, the paper presents a general simulation model created in this research to investigate the impact of production planning and control policy to the performance of the dedicated remanufacturing of electronic products. A factorial design based cell evaluated genetic algorithm (CEGA) is also developed and applied to optimize the remanufacturing system based on the simulation model developed.

The rest of the paper is structured as follows: following this introduction, the characteristics and problems of a dedicated remanufacturing system and related research work are illustrated in Section 2; this is followed by Section 3 which provides a discussion of the general simulation model for dedicated remanufacturing; the hybrid CEGA simulation optimization approach is also included in the section; Section 4 provides a detailed case study of the simulation model and the CEGA simulation optimization approach; Section 5 concludes the paper and provides suggestions for future research in remanufacturing.

2. Related research in remanufacturing

Researchers have concentrated their efforts on remanufacturing with the combined model. This includes qualitative modeling of the whole product recovery infrastructure and quantitative modeling of the single operations that compose the system. Hoshino et al. (1995) addressed the influence of the demands in the past production periods to the future return of end-of-use products. Laan (1996) gave a numerical comparison of alternative strategies for product remanufacturing and disposal. Kasmara et al. (2001) focused on the two flow characteristics and return process that occurred in the remanufacturing/manufacturing combined production system. Murphy (2003) analyzed and compared material flows and cost for electronics disposition among three decades from the 1980s to 2000s. White et al. (2003) analyzed the whole supply loop from forward manufacturing to remanufacturing and presented a generalized overview of a reverse manufacturing process for computers based on their definition of remanufacturing and demanufacturing. They also described in more detail the important aspects and challenges in the acquisition, assessment, disassembly and reprocessing of computer equipment as it moves through their reverse manufacturing process. Alberto et al. (2002) studied the construction of an industrial plant for the decontamination and recycling processes of end of life vehicles that was being planned in Navarra (Spain). They provided a modeling framework that integrates different Operations Research methodologies including queueing networks, optimization with simulation, evolutionary computation and multi-objective methods. Zhang et al. (2004) presented a web-based decision support and evaluation system for operations in remanufacturing and recycling including electronic product disassembly, materials recovery, and recycling management. An overall evaluation of the product's lifecycle environmental impact considering EOL dispositions was also provided. Comprehensive product analysis and environmental impact assessment were discussed in their paper.

As an important factor involved in remanufacturing, uncertainty was recognized and studied in many published works. Mula et al. (2006) provided an extensive review of uncertainty modeling in general production planning. As to remanufacturing, two types of uncertainty were addressed by researchers: product return uncertainty and demand uncertainty. Most works in remanufacturing used analytical models and simulation models to address impact of return uncertainties to logistics network design and inventory control policies. Salema et al. (2007) proposed general two-stage stochastic mix integer model for reverse logistics network design considering product demand and return uncertainty. Capacity limits and multi-product were also considered in their model which was solved using standard B&B techniques. Lister (2007) developed a similar two stage stochastic programming method for network design of a closed loop system. Based on the integer L-shaped method, a decomposition approach is used to find the efficient solution. Biehl et al. (2007) used a simulation model to analyze the impact of the system design factors as well as environmental factors impacting the operational performance of the carpet reverse logistics. Their aim was to provide guidance for designing a new system of reverse logistics in carpet industry considering return uncertainty. With a conclusion that existing reverse logistics in US is insufficient for handling the return requirement, the paper provided possible management options to address this problem, including legal responses to require return flows and the use of market incentives for recycling. Zikopoulos and Tagaras (2007) investigated the impact of quality uncertainty to reverse logistics with stochastic demands in a single-period setting. The conditions to use only one of the collection sites are identified based on optimal system profitability. Zikopoulos and Tagaras (2008) also impact of the sorting procedures to the cost of reverse logistics considering the uncertainty about the remanufacturability of used products.

For the inventory control of remanufacturing, Fleischmann et al. (2000), and Fleischmann and Kuik (2002) studied an optimal inventory control for combined reverse products with independent stochastic item returns. Minner (2001) addressed the safety stock planning in a closed loop supply chain with external and internal stochastic product return and reuse. Kiesmuller and Minner (2003) investigated the problem of computing the produce-up-to level S and the remanufacture-up-to