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Quality, Reliability, Maintenance Issues in Closed-Loop Supply Chains: A Review

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Abstract: The collection and recovery of end-of-life products has been a very successful research area especially around the design of reverse logistics and remanufacturing processes. Unfortunately, there is very little work on the issues of quality, reliability, maintenance & warranty for these recovered products and the remanufacturing activities that will take them to their subsequent lifecycles. This paper reviews recent and relevant literature on quality, reliability, maintenance and warranty problems in closed-loop supply chains with a focus on the remanufactured or second-hand products. A variety of mathematical tools and techniques used in the literature are mapped to the main issues considered. The findings are summarized, and the main research issues and opportunities are highlighted.

Keywords: Remanufacturing, Refurbishing, Reuse, Quality, Reliability, Maintenance, Warranty.

1. INTRODUCTION

In the past decade, a large quantity of research work was published on Green supply chain management (GSCM) covering mainly the aspects of logistics, optimal inventory control policies for returned products and recovered parts, remanufacturing production planning, and supply chain design decisions. However, key areas areas such as quality, reliability, maintenance engineering and warranty policies for remanufactured systems or second-hand products (SHP) have been ignored. The reliability of the products recovered is an important factor in the remanufacturing decisions to be made. Once refreshed, the product or part will have to survive a second lifetime and be required to provide the consumer with a decent performance level. The maintenance and warranty policies to be implemented and offered also have to be carefully determined and matched to the refreshed product's reliability. Where one can find thousands of models on closed-loop supply chain models dealing with SHP, Shafiee and Chukova (2013b) have found that, 'in contrast with the vast literature on new products, a brief review shows that only a few researchers have worked on developing models to jointly determine the optimal warranty policy, the upgrade strategy (as an engineering issue to reduce warranty servicing cost), and sale price (as a competitive tool in marketing strategy) of a SHP to maximize the dealer's expected profit. This paper reviews recent and relevant literature on quality, reliability, maintenance and warranty problems in closed-loop supply chains with a focus on the remanufactured or SHP. A variety of mathematical tools and techniques used in the literature are mapped to the main issues considered. The findings and interpretations are summarized, and main research issues and opportunities for future research work are highlighted. Remanufacturing is the process of restoring used products to like-new conditions by disassembly, cleaning, repairing and replacing parts, and reassembly (see Chari et al. (2014)). According to Parkinson and Thompson (2003), the aim of remanufacturing is to reprocess used products in such a manner that the quality of the products is as good or better than new in terms of appearance, reliability and performance. Various other definitions of remanufacturing exist in the literature (see Parkinson and Thompson (2003)). Remanufactured systems are commonly regarded as having lower quality when compared to original equipment but this is not always the case as reported by Parkinson and Thompson (2003). In order to stimulate the demand for remanufactured or SHP, remanufacturers, dealers/brokers use a combination of initiatives to promote and infer the quality of their products. These initiatives include significant price reductions, generous warranty coverage, free preventive maintenance (PM) on top of the upgrade and repair activities that take place during remanufacturing.

2. LITERATURE REVIEW

The objective of this paper is to identify major research peer-reviewed publications dealing with quality, reliability, maintenance and warranty models for SHP. This review focuses upon books, peer-reviewed conferences papers and journal papers published after 1985. Most academic research databases such as Engineering village (Compendex), Proquest, Google Scholar were queried using some important keywords such as 'second-hand', 'reconditioned', 'refreshed', 'remanufactured' in combination with 'upgrade', 'warranty', 'maintenance', 'reliability', 'models'. The articles obtained were classified using both their problem context and methodology context (See table 1). The bibliographic formatting used by this publication does not allow for a numbered reference list. Thus, in order to keep the mapping table small, we added a numerical label [..] at the end of each publication to be used for cross-referencing between the table and the references.

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2.1 Classification Based on Problem Context

Quality models: Behdad and Thurston (2011) proposed a model to evaluate the stochastic variability in the quality of returned components. Dindarian et al. (2012) evaluated microwave ovens discarded in the United Kingdom to determine the quality of the discarded products failures and quality levels. Guide Jr et al. (2003) developed a framework including a heuristic nonlinear programming approach to maximize the profitability of cellular telephone recycling program. The profitability varies according to the quality and quantity of the returned product and on the demand for remanufactured phones. Shrivastava et al. (2005) proposed a decision making system which uses material contents and quality levels to reach a rating score. Galbreth and Blackburn (2006) developed an optimal acquisition and sorting policy. In order to reduce the uncertainty in quality, a stochastic algorithm is used to minimize the acquisition cost and for sorting the products. Pokharel and Liang (2012) developed an acquisition policy for a consolidation center to maximize their profit while meeting the price quantity and quality levels set by a remanufacturer. Nikolaidis (2009) proposed a mixed integer programming model for the optimal acquisition of products for remanufacturing purposes. Radhi (2012) proposed a mixed integer nonlinear program to maximize the expected profit by using less resources and optimal minimum quality products to meet multiple markets demand. Their results indicated that the increase of uncertainty in quality and demand reduces the profit. Vorasayan and Ryan (2006) formulated an open queueing network model to minimize the cost of refurbishing operations and to maximize the manufacturers expected profit. Zikopoulos and Tagaras (2007) studied the impact of uncertainty in quality of the returned products on refurbishing actions. Huang (2010) investigated incentive policies offered for returns using Stacklebergs game theory models.

Reliability models: Huang and Askin (2003) performed a reliability analysis of electronic devices with multiple competing failure modes including aging induced performance degradation. Mazhar et al. (2007) proposed a neural network model to determine the remaining life of electric motors in washing machines. Jiang and Guo (2014) developed a non-parametric method to estimate the failure intensity function of repairable products which can be used in the assessment and analysis of product sustainability. Aksezer (2011) used regression analysis to determine the reliability of second-hand cars from manufacturers perspective. Kara et al. (2005) proposed a multicriteria decision making model to estimate the remaining life of products. Pochampally and Gupta (2004) developed a Bayesian updating process to be used during the grading process. It also tracks the quality and reliability of the product and helps to minimize human errors. To estimate the lifecycle costs and replacing requirements of parts, Jiang et al. (2000), Jiang et al. (1999) developed a reliability model for a population of systems undergoing remanufacture and studied the replacement rate behavior in this population. Shu and Flowers (1998) estimated the lifecycle cost of remanufacturing used systems and conducted an experiment on a mechanical gear system. Diallo et al. (2014) derived a cost optimal mixing strategy and studied the behavior of the failure rate of a lot composed of new and reconditioned parts. Murayama and Shu (2001) designed a reliability model for product reuse without repair. Time to failure and quality deterioration data are used to simulate the material flow all through the product lifespan. Kim and Park (2013) proposed an integrated data system based on a RFID technology to provide useful data that can be used to make remanufacturing more efficient.

Maintenance models: Maintenance is defined as a series of actions taken during the use of a product to enable it to the function at predetermined levels during its economic lifetime (Parkinson and Thompson (2003)). Because of their potential lower reliability, SHP need appropriate maintenance models. Ait-Kadi et al. (1990) developed a block replacement policy (BRP) relying on old components for replacements. Yeh et al. (2011) developed two PM strategies: one with fixed maintenance degree and the other with an age threshold. Numerical results show that PM reduces the total expected cost and increases the profit. Pongpech et al. (2006) proposed an optimal upgrade and PM strategy for SHP under lease. They suggest to upgrade before leasing. In addition, PM lowers the failure rate and total expected cost. Sheu and Griffith (2002) extended the BRP with shock models. Boudhar et al. (2014) developed a new dynamic heuristic for the optimization of opprotunities to use new and remanufactured spare parts in a context of stochastic degradation. Shafiee and Chukova (2013a) proposed a taxonomy scheme to classify maintenance and warranty models.

Remanufacturing models

Disassembly / replacement: Remanufacturers get their inventory of spares through the disassembly of failed products. Improper design leads to more wastage and electronic products with minor faults are not reused (Dindarian et al. (2012)). Proper design helps disassembly of failed or returned products which leads to better reuse. Shrivastava et al. (2005) proposed a decision making system to optimize the disassembly strategy. Their system helps the remanufacturers to assess the time duration of the recycling process. Propst and Griffin (2000) developed a reliability assessment model for the remanufacturing of oil circuit breakers. Chari et al. (2014) proposed a framework for sustainable product life-cycle in remanufacturing. Their review showed that very few models have been developed in the field of remanufacturing operations.

Upgrade: According to Parkinson and Thompson (2003), upgrade refers to a process that gives a product enhanced functionality. Naini and Shafiee (2011) proposed an optimal upgrade strategy and price for the SHP under warranty using 3 decision variables: past age, upgrade action and warranty period. A case study is conducted on electrical drills with real data from a dealer. Shafiee et al. (2011b) developed a stochastic cost benefit analysis to optimize the investment made in the upgrade actions for the SHP with a failure free warranty. The results indicate that the decision to improve components reliability before selling is more profitable, than a product sold without improvement. Khatab et al. (2013) developed a mathematical model to investigate the interactions between the upgrade level decisions, the optimal maintenance policy decisions and the total costs incurred during the lifetimes of these refreshed systems. Lo and Yu (2013) derived a preventive maintenance model for stochastic degradation