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Inventory control policies for inspection and remanufacturing of returns: A case study

George Nenes [a,*], Sofia Panagiotidou [b], Rommert Dekker [c]

[a] University of Western Macedonia, Department of Mechanical Engineering, Bakola & Sialvera, 50100 Kozani, Greece
[b] Aristotle University of Thessaloniki, Department of Mechanical Engineering, 54124 Thessaloniki, Greece
[c] Erasmus University Rotterdam, Econometric Institute, PO Box 1738, 3000 DR Rotterdam, The Netherlands

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ABSTRACT

When both purchase of new products and remanufacturing of returned products constitute options for a company, it faces a trade-off between the long purchase lead times and the high purchase costs versus the uncertainties generated by the unknown a priori quantity and quality of returns. In other words, although the remanufacturing of returns is generally a faster and less expensive alternative for a company, compared to the procurement of new products, both quality and quantity of returns are unfortunately highly stochastic. In such cases, companies have to select the ordering and remanufacturing policy so as to maximize their performance according to specific criteria, e.g., minimize the expected cost or maximize the expected profit. In this paper we investigate alternative policies for a system where both demand of new products and returns of used products are stochastic. The expected cost of each policy for a real application problem is computed and the best policy is proposed. A numerical investigation is also conducted in order to identify the best policy under various alternative scenarios.

1. Introduction

During the last years, companies are considering to use remanufacturing operations besides the traditional manufacturing ones, mainly due to economic and legislative incentives. The remanufacturable products can be sold to B markets at a lower price, compared to the price of new products, e.g., tires (Ferrer, 1997), copiers (Ayres et al., 1997), cell phones (Nikolaidis, 2009) or they can be used to satisfy demand of the same markets, e.g., single use cameras (Toktay et al., 2000), pallets and containers (Golany et al., 2001, Kelle and Silver, 1989), car service parts (Driesch et al., 2005) and computer parts (Fleischmann et al., 2003).

This trend in the industry has led several researchers to investigate such problems and develop appropriate models to account for cases where recovery of used products is an additional option for the company. This paper is also motivated by a specific case that involves both manufacturing and remanufacturing options. Its purpose is to investigate the alternative options concerning the inventory control when the decisions for the company in order to satisfy demand are threefold instead of twofold as was assumed in almost all earlier papers. These three options are presented in Fig. 1 and are the following: (a) order of new items, (b) inspection of returned items which can be either as good as new or remanufacturables and finally (c) remanufacturing of items that upon inspection are found to be remanufacturables. The goal is the minimization of the expected cost of the system in an infinite time horizon. The problem setting has the following special characteristics which complicate the optimization procedure.

- There is a limited supply of returns.
- Both demand of new products and returns of used products are assumed to be random variables in contrast to most approaches that assume deterministic demand and/or returns.
- Returned products may actually be as good as new or remanufacturables. Thus, there are three different types of inventory, i.e., good, remanufacturables and uninspected items in contrast to the usual practice of having only two types of inventory (good products and remanufacturables).
- The lead time of alternative decisions varies. It takes less time for a product to be remanufactured than for an order to be delivered while the inspections are almost instantaneous.
- It is not obvious what the best policy for satisfying the demand should be. There could be considered numerous alternative options like inspection upon return, remanufacture immediately after inspection, etc.

* Corresponding author. Tel.: +30 24610 56600; fax: +30 24610 56601.
E-mail addresses: gnenes@uowm.gr (G. Nenes), span@auth.gr (S. Panagiotidou), rdekker@few.eur.nl (R. Dekker).

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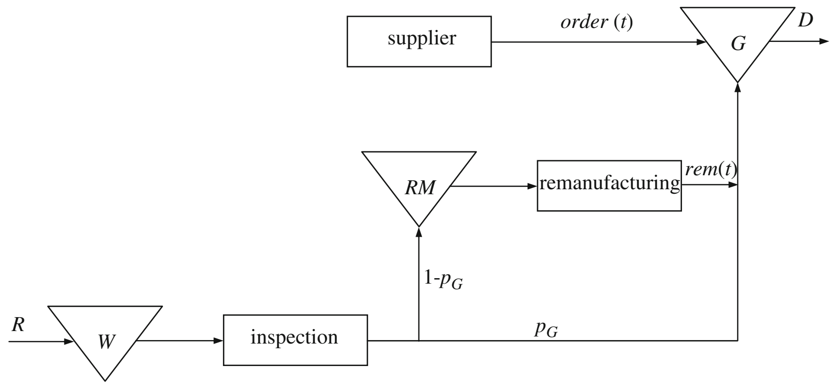

Fig. 1. Inventory control scheme with inspection and remanufacturing of returns.

Specifically, the product under study in this paper is the "relay", a device which is used by the Dutch Railways to constantly monitor the tracks. These devices register if a train passes a particular point in the railway network. They are regularly replaced but most of the times these replacements are done as a precaution (preventive replacements). Thus, the proportion of relays that are replaced but are still in an as-good-as-new condition is relatively high. The company that handles these relays will be called by the fictitious name RP for confidentiality purposes. RP has a contract which dictates that all relays necessary for the Dutch Railways have to be bought from RP and all relays that are replaced have to be returned to RP. The focus of the present paper is the optimization of the inventory control and ordering process of RP.

As soon as a relay is returned to RP, it is inspected immediately and classified to be either in an acceptable or in a bad condition. This inspection is done visually and checks if the rail maintenance contractors have unintentionally damaged the relays by being careless. Without loss of generality, it is assumed that the bad relays are filtered out of the return stream and we will further concentrate on acceptable returns only.

As soon as the first inspection is completed the relays are sent to RP's warehouse and stored until the second inspection. The second inspection is the one that will reveal whether each relay is in an as-good-as-new condition or needs remanufacturing. We only consider those types of relays that can be remanufactured. The selection by the first inspection ensures that all relays can be remanufactured. If a relay passes this second inspection, it is classified as good and it can be used immediately to satisfy the demand or it can be stored. If the inspected relay needs remanufacturing, it can be either remanufactured or stored. Thus, the company keeps stocks of (a) good relays, (b) remanufacturable relays and (c) uninspected relays (see also Fig. 1). The holding cost is not the same for all stock types.

This paper, apart from describing the currently used policy by RP, also introduces new policies with various priority rules and various decision criteria. The main objective is to investigate whether the current policy is the optimum one, in terms of the resulting average cost, given the problem characteristics and cost parameters. A secondary target of the paper is to investigate the relative economic effectiveness of various policies under numerous alternative scenarios concerning the costs and the statistical characteristics of the problem.

The remainder of the paper is structured as follows. Section 2 presents the related literature while Section 3 presents the nomenclature that is used throughout the paper and describes two policies where safety stocks are used in order to reduce the stockout probabilities of each period. In Section 4 two alternative policies are introduced, that approach the problem in a somewhat different way, i.e., the stockout probability of each period is analytically computed and based on its value the company can decide the amount of relays that will be sent for remanufacturing as well as the order quantity of new relays. In Section 5, three extreme policies that also employ the stockout probability are introduced. Section 6 presents the cost elements as estimated by the company and the probability density functions of the demand of new relays and the returns. By using these characteristics the average cost of each policy is computed and the best policy can be selected. In the same section an illustrative example for the implementation of each policy is presented, various alternative scenarios are investigated and opportunities for additional cost reduction are introduced. The main findings of this paper are summarized in the final section.

2. Literature review

A substantial number of papers has appeared in the literature that deal with cases where both returned and new products are used to satisfy the product demand; however the specific characteristics of each paper may differ significantly. More specifically, the focus may be on production planning and inventory control or on inspection and sorting of returns in order to identify their quality and organize the necessary activities for their recovery. In addition different recovery options may be considered including recycling, repair or remanufacturing. Moreover, the optimization procedure and the suggested policies are also strongly dependent on the time horizon since in many cases those problems are dealt as single period problems.

In the present paper, we are mainly interested in remanufacturing models where returns and demands are assumed to be independent random variables. For the inventory control of such systems both continuous and periodic review is considered, while the suggested policies can be classified as "push" or "pull" control policies. In push policies all returned items are assumed to be remanufactured as soon as they arrive, while in pull policies the decision to remanufacture is driven by demand. In any case though, all related models include two types of stock at most: one with serviceable items and one with remanufacturable items. From this point of view the problem studied in this paper is much more complicated since it generally includes an additional stock regarding the returned items that are waiting for inspection which may be either as good as new or remanufacturable. Thus, our problem incurs an additional complexity regarding the quality of returns; the decisions that have to be made concern not only the number of remanufacturable items that has to be