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► To cite this version:

Lâm Laurent Lim, Simme Douwe Flapper, Jean-Philippe Gayon. Optimal control of a hybrid production/remanufacturing system using one shared resource. ROADEF 2011, Mar 2011, Saint-Etienne, France. hal-00821785

HAL Id: hal-00821785

<https://hal.science/hal-00821785>

Submitted on 13 May 2013

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Optimal control of a hybrid production/remanufacturing system using one shared resource

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Keywords: *remanufacturing, shared server, optimal policy, heuristics, Markov processes, quasi-birth-death processes*

1 Introduction

1.1 Reusing product returns

There are several reasons why companies consider reusing products: the growth of environmental consciousness, legal obligation, costs reduction, open potential new markets etc. Returns complicate the inventory control and integrating the return flow of used products into the materials planning is a key issue in reverse logistics.

1.2 Hybrid production and remanufacturing systems

In our problem, a company can use both a remanufacturing facility to sell returned products and a classical production facility to satisfy the demand that cannot be fulfilled by returns. Such systems are called hybrid production/remanufacturing systems and have received a growing attention in recent years. To perform production and remanufacturing, a company can use dedicated or shared resources. Sharing resources increases the flexibility of the system but complicates the production/remanufacturing control. The study of [1] is one example of a concrete application of a hybrid system with shared resource in the automotive industry.

2 Model formulation

We consider a single-product production-inventory system with independent product returns. Returned items require remanufacturing operations (always successful) before being sellable again. Production and remanufacturing operations are performed by a single shared resource. Switching times and costs are neglected. Customer demand can be fulfilled without distinction by either newly produced or remanufactured products. Two inventories are considered: the remanufacturable inventory composed of product returns, and the serviceable inventory composed of new and remanufactured products. We use a continuous-time model with Markovian assumptions: demands and returns follow independent Poisson processes, production and remanufacturing times are

exponentially distributed. We further assume linear holding and backlogging costs. We want to find the optimal policy that minimizes costs (under discounted and average cost criteria).

3 Structure of the optimal policy

3.1 Optimal policy in the general situation

We show that the optimal policy structure seems to be complex in the general case. However, we prove that if the remanufacturing rate is larger than the production one and the remanufacturing holding cost is larger than the serviceable one, then it is optimal to repair returned products as soon as possible: in this case, the optimal policy belongs to the class of policies with priority on returns.

3.2 A characterization of the optimal policy with priority on returns

Using Markov decision processes [2], we characterize the optimal policy for the class of policies where returns have priority over the production. For the discounted cost criteria, the optimal policy is the solution of a fixed-point equation [2]. Based on structural results for queueing systems [3], we show that the optimal policy is a base-stock policy: the server produces new products if and only if the serviceable inventory is below a certain threshold. Then, this result is extended to the average cost criteria, as explained in [4].

4 Algorithm to compute the optimal policy parameters and heuristics

Stochastic dynamic programming can be used to compute the optimal policy parameters for both discounted and average cost criteria. However, for policies with priority on returns, we provide a faster method. When considering a base-stock policy, we show that the system evolves according to a quasi-birth-death process [5]. Because of the special structure of the generator matrix Q associated to this process, we use a matrix-geometric approach [5] to compute the steady-state probabilities. The advantage of using this method is to reduce the sizes of matrices that are required for computations. Because computations may be time consuming, we provide heuristics for approximating the optimal policy parameter. To derive these heuristics, we modify the exact formula of the optimal base stock level for a make-to-stock queue with direct returns [6].

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