Dynamic production, remanufacturing and disposal control of a MTO manufacturing/MTS remanufacturing system

Tanja Mlinar
IÉSEG School of Management (LEM-CNRS), 1 Parvis de La Défense, 92044 Paris La Défense Cedex, France
{t.mlinar}@ieseg.fr


1 Introduction

We consider a company that possesses a single production facility used for production of new and remanufacturing (product recovery) of used/defected products. Orders for new products are processed in a Make-to-order (MTO) fashion and should be satisfied within the promised due dates. Remanufactured products are make-to-stock (MTS) and are sold in the secondary market with a lower price than a manufactured product. Product returns for remanufacturing are uncertain as well as the demand for the manufactured and remanufactured products.

In order to maximize the expected profit of the company, the problem under consideration is to determine whether to produce or to remanufacture an item by its limited production capacity, and how many product returns and customer orders for manufactured products to accept. Product returns, if accepted, will be stored in a limited inventory incurring an unit inventory holding cost per period. If rejected, we consider two cases that can occur in practice: the company gets a salvage value per each unit resold as a scrap; or if a returned product is not resalable, the manufacturer disposes rejected units incurring an unit disposal cost. If the decision is to remanufacture a returned item, the item is taken from its stock and upon remanufacturing it, it is stored in the limited inventory for remanufactured products. If the decision is to manufacture a new product, the product will fulfill an order in the same period (thus, no earliness cost incurs).

The related literature focuses on MTS production-inventory systems with a joint inventory for newly manufactured and returned products sold as new ones (see e.g., [1, 2]), and hybrid MTS systems with separate inventories used to satisfy demands for new and remanufactured products, and product substitution (see e.g., [3, 4]). Our study contributes to the literature as it considers a MTO manufacturing and MTS remanufacturing system with a single production facility and separate inventories.

2 Problem description

We model the optimal control problem as a discrete-time Markov Decision problem to obtain the admission and production policy that will maximize the total expected profit of the company. In each period there is an unit of production capacity. Unit processing times of two types of products are identical and equal to one period. The promised due-date lead time of new manufactured products is fixed and given by $L$ periods.

The order of events in each period is as follows. First, the company decides whether the current available capacity will be used to remanufacture an item or to produce an unit of already accepted not processed MTO item, if any. Remanufacturing is possible only if there is at least
one item in the inventory of the product returns and if the inventory of the remanufactured
products is not full. If the decision is to (re)manufacture an item, the item will be processed
by the end of the day. Second, the demand for remanufactured products occur and it will be
satisfied depending on the current inventory level at the end of the period. Thus, the company
generates the profit per unit of satisfied demand \( p_r \). Third, the company decides on the
amount of MTO demand to accept based on the admission policy and the available capacity
within the lead time. The profit per unit of accepted MTO demands \( p_m \) will be generated and
the corresponding available capacity within the lead time will be allocated for newly accepted
MTO demand. If a new product is produced in the current period, the company fulfills an
order at the end of the period. Fourth, there might be arrivals of return products which are
accepted/rejected based on the admission control for product returns and its current inventory
level upon the production decision. For each product return rejected, the company pays the
disposal cost per unit \( -p_r < c_d < h_d \), where \( h_d \) is an unit inventory holding cost of return
products).

The state of the system is described by \( (i_d, i_r, X) \), where \( i_d \) and \( i_r \) denote the inventory level
of product returns and remanufactured products, respectively \( (i_k = (0, 1, \ldots, I_k) \) where \( I_k \) is
the maximum inventory level for \( k = \{d, r\} \), and the vector \( X = (x_1, \ldots, x_L) \) denotes whether
the capacity in each period within the due-date lead time \( (L) \) of the incoming orders for new
products is reserved or not (e.g., \( x_1 = 1 \) if the capacity in period 1 is reserved, and \( x_1 = 0 \) if
available). Thus, the system state space is \( 2^L \cdot (I_r + 1) \cdot (I_d + 1) \). Linear programming is used
to solve the MDP formulation.

In the numerical experiments performed, we consider two types of arrival processes : Uniform
and Poisson process, and different values of the parameters. In particular, the maximum values
of \( L, I_d, \) and \( I_k \) were set to 8 as extracting the optimal control rule by using a personal laptop
with 8GB of RAM is a time consuming task for larger instances. Our preliminary results
demonstrate significant outperformance of the proposed rule compared to the benchmark policy
that accepts product returns as long as their inventory is not full. For instance, the largest
increase in the gap is observed when \( h_d \) increases. In particular, for \( h_d = 1.25 \cdot h_r \), the average
gap for the considered set of instances is 15.36% compared to 4.30% for \( h_d = 0.5 \cdot h_r \).

As a future research, to reduce the state space of the system, a heuristic that aggregates the
information about reserved capacity within \( L \) should be implemented as in [5, 6].

RÉférences

[1] E Kim, S. Saghafian, and M.P. Van Oyen. Joint control of production, remanufacturing, and
disposal activities in a hybrid manufacturing-remanufacturing system. European Journal
system with product returns and two disposal options. European Journal of Operational
stochastic manufacturing/remanufacturing system. Computers & Industrial Engineering,
ring/remanufacturing system with product substitution. Computers & Industrial Enginee-
demands and strict due dates. International Journal of Production Research, 54(20) : 6156–
6173, 2016.