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The market-oriented dynamic product recovery model in the just-in-time framework

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Abstract

A market-oriented deterministic dynamic product recovery problem and its multi-echelon model formulation are discussed in this paper. For this general non-linear alternate deterministic dynamic product recovery model a dynamic programming solution procedure is developed. Furthermore, the subcases of the Just-in-time situation with regard to the suppliers as well as customers are considered, for which the two-stage problem is transformed to easily solvable one-stage models. It will be seen that the regarded recovery problem in this formulation is just a special multi-echelon problem with two alternative production options.

Keywords: Product recovery; Just-in-time; Lot sizing; Inventory management

1. The general alternate deterministic dynamic product recovery problem

In a previous publication a new product recovery model was investigated by one of the authors (Richter and Sombrutzki, 2000). At first, we will briefly describe this model for a firm using two product alternatives to satisfy the one product demand. The demand D_t of a certain product for the periods $t = 1, 2, ..., T$ can be satisfied by items which have been either recovered from used products (non-serviceables) arriving in the quantity of d_t at the beginning of period t, or have been newly manufactured (or produced, or bought from outside). The data s_t, r_t express the setup cost for making new products or recovering used products, respectively, and the variables z_t, x_t denote their quantities. We do not distinguish between remanufactured and newly produced items in the stock of final products, i.e. all final products are considered to have the same value for the customer. Therefore, two different inventory levels have to be considered: The inventory level for the final products I_t, with unit inventory cost of H_t per period, and the inventory level i_t for arrived used products, with unit inventory cost of h_t per period. As in the original Wagner/Whitin model, the equations $I_t = I_{t-1} + x_t + z_t - D_t$ describe the final product inventory process, and the additional equations $i_t = i_{t-1} - x_t + d_t$ model the used product inventory process. The goal is to minimize the total cost for T periods, i.e. the total setup cost

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and holding cost for recovering and manufacturing. Then the following model arises:

$$i_0 = I_0 = 0, \quad i_t = i_{t-1} - x_t + d_t,$$
$$I_t = I_{t-1} + x_t + z_t - D_t,$$
$$I_t, x_t, i_t, z_t \geqslant 0, \quad t = 1, 2, \ldots, T,$$
$$\sum_{t=1}^{T} (r_t \operatorname{sign} x_t + s_t \operatorname{sign} z_t + h_t i_t + H_t I_t) \to \min. \quad (1)$$

Since there is an uncontrolled back flow of used products, in the worst cases, the problem can be either unsolvable, or the amount of stored non-serviceables at the end of the planning period T can be very high. How to estimate the latter situation is not clear, for there is no information on the demand for the periods behind T. This is the reason to model the recovery problem with respect to a certain market approach: used products as well as the material for the production of new products will be bought from the market as resources for the recovery process (cf. Fig. 1).

The market-oriented problem can be modeled in the following way: There are two alternatives $j = 1, 2$ to satisfy the demand D_t. Either the material is ordered and new products are produced by the first alternative or non-serviceables are ordered and the product recovery process is applied by the second alternative. The order variables will be denoted by r_{1t}, r_{2t} and the production/recovery variables by x_{1t}, x_{2t}, respectively. The variables i_{1t}, i_{2t} denote the stocks of material and non-serviceables at the producers site and I_t the stock of final products (cf. Fig. 2).

The inventory stocks for the material, for the used products and for the final products are modeled by the following equations:

$$i_{jt} = i_{jt-1} + r_{jt} - x_{jt},$$
$$I_t = I_{t-1} + \sum_{j=1}^{2} x_{jt} - D_t,$$
$$i_{jt}, I_t, x_{jt}, r_{jt} \geqslant 0, \quad i_{j0} = I_0 = 0,$$
$$j = 1, 2, \quad t = 1, 2, \ldots, T. \quad (2)$$

The positive cost inputs cover the ordering cost, the production/recovery process cost and the various inventory cost. The sum of the ordering cost $p_j(x) = p_{sj} \operatorname{sign} x + p_{vj} x$, of the production/recovery process cost $c_j(x) = c_{sj} \operatorname{sign} x + c_{vj} x$, of the material/used products inventory cost $h_j i_{jt}$, and of the unit final product inventory cost HI_t set up the total cost which are minimized in the following objective function (3):

$$\sum_{t=1}^{T} \left(\sum_{j=1}^{2} [p_j(r_{jt}) + h_j i_{jt} + c_j(x_{jt})] + HI_t \right) \to \min. \quad (3)$$

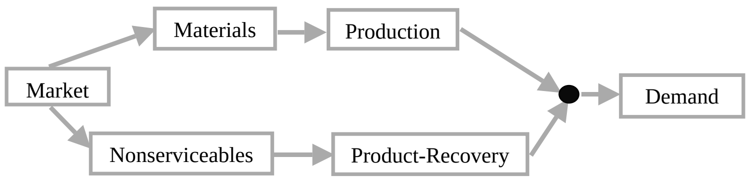

Fig. 1. The market-oriented recovery problem.

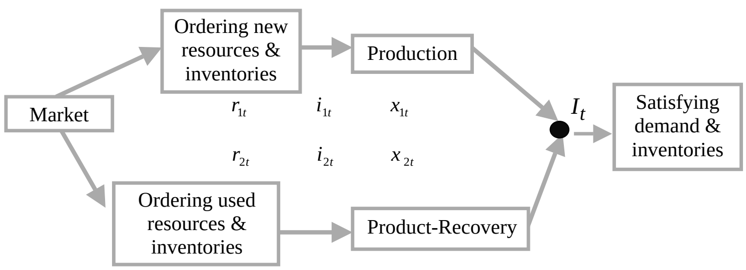

Fig. 2. Variables of the market-oriented recovery problem.