

On an Optimal Production-Inventory Plan for a Closed Loop Supply Chain.

Oscar Salviano*
Frederic Andres**

*Center for Information Technology Renato Archer
BRAZIL (Tel: +55 19 37466036; mail: oscar.salviano@cti.gov.br).

**National Institute of Informatics, 101-8430 JAPAN (e-mail: andres@nii.ac.jp)

Abstract: Middle and long-term inventory-production plans have deserved interest of managers of supply chains since the 80's. However, from 90's to now, to plan a reverse channel has been also an important business practice. This paper deals with such an issue. In this way, a chance constraint, stochastic quadratic problem subject to linear discrete-time inventory-production systems is formulated. The objective of this problem is to meet the demand for a single product, which can be manufactured from a forward channel and/or remanufactured (refurbished) from a backward channel. The demand fluctuation is a random variable, with mean and standard-deviation known over time. On the other hand, the return rate is assumed deterministic, but with some periods of delay over the planning horizon. The random nature of demand fluctuation affects the variability of serviceable inventory variable in the sense of its variance increases over periods of planning horizon. In order to mitigate such variability, a feedback gain, which relates remanufactured/refurbished rate to serviceable inventory level, is considered. This gain is obtained from a minimum variance problem. As a result, an optimal plan is developed from an equivalent Mean Value problem that has constraints regulated by the gain. Through a simple example, it will be shown that the open-loop optimal plan obtained with problem's constraints fixed by optimal gain has a better performance than the optimal plan provided without such a gain.

© 2017, IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd. All rights reserved.

Keywords: minimum variance, open-loop system, optimization, supply chain, reverse logistics.

1. INTRODUCTION

According to Govindan et al (2015), reverse logistics is one of the important issues that all supply chains must deal with. In fact, due to many reasons, among them environment impact that is closely related to sustainability of planet, the need for planning a reverse channel has become a priority for managers of supply chains. This priority is surely related to image and costs aspects of supply chain. Thus, taking care of products after using not only can reduce the costs particularly due to reuse of parts but can give a good image to the supply chain, particularly showing its concern about planet's preservation; see Chin et al. (2015). Typical activities of planning, implementing and controlling the flow of material throughout the forward channel of the supply chain, is replicated throughout the reverse channel. The main role of reverse logistics is to move products from their final destination for the purpose of capturing value, or proper disposal. In short, reverse logistics can be understood as the process of collecting, recycling, repairing, remanufacturing, refurbishing and disposing used products to reduce waste.

Several papers found in literature discuss themes related to strategic and operational aspects of reverse logistics systems; see Govindan et al. (2015). Part of them uses quantitative models to represent remanufacturing (refurbishing) activities in the reverse channel (Decker et al., 2004). A typology of quantitative models for reverse logistics based on three

classes of problems is discussed in Fleischmann (2001). Basically, they can be described as (i) reverse distribution problems; (ii) inventory control problems in systems with return flows; and (iii) production planning problem with reuse of parts and materials. The first problem considers the collection and transportation of used products and packages; the second is related to control mechanisms that allow collecting used products into the marketplace; and the third considers the planning process of reusing items, parts, and products without remanufacturing/refurbishing.

The second class of problems of above typology is the main interest here. According to Fleischmann (2001), such problems can be decomposed into two distinct categories of problems, that is: *repair problems*, where failed items are replaced by spares; and *product recovery problems*, where used-products are remanufactured/refurbished and then replaced into the marketplace. This last category considers problems with special forward and backward production-inventory systems that take into account products that are delivering into the marketplace, collecting after life cycle and remanufacturing/refurbishing or disposing of; see Zhao et al. (2016) and Lee et al. (2017). Additionally, if demand is not known exactly (i.e., it has random fluctuation), production-inventory system is a stochastic process, which implies to deal with continuous or discrete chance-constraint stochastic optimal control problems; see Silva Filho & Andres (2016).

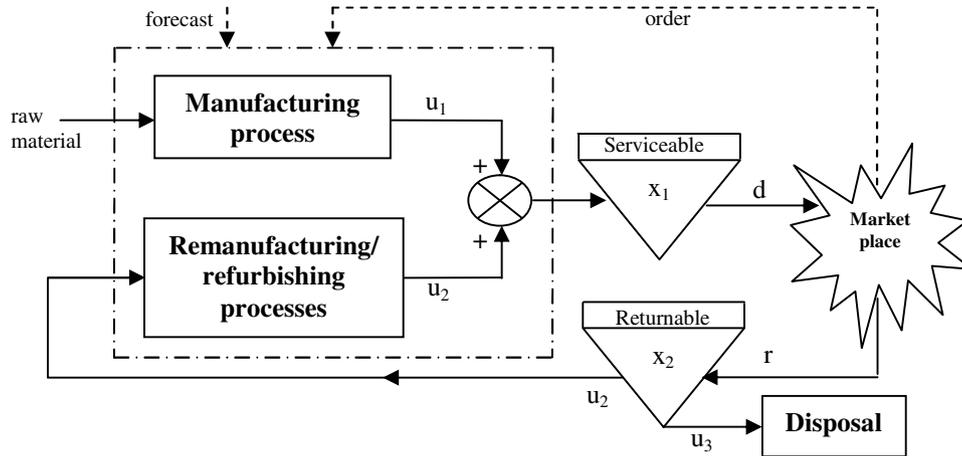


Fig. 1. Forward and reverse channel of closed-loop supply chain

In this paper, we revisit and formulate the chance-constraint, stochastic quadratic problem (Adam et al. 2016) subject to linear discrete-time inventory-production systems. The objective of this problem is to meet the demand for a single product, which can be manufactured from a forward channel and remanufactured (or refurbished) from a reverse channel. The demand fluctuation is a random variable, with mean and standard-deviation known over periods of planning horizon. On the other hand, the rate of return is deterministic. Its value is taken from past demand with delay that depends on the life cycle of the product. The random nature of demand fluctuation affects the variability of serviceable inventory variable in such way that variance increases over the periods of planning horizon. In order to mitigate such variability, a feedback gain is provided from a minimum variance problem. The gain relates linearly remanufactured (refurbished) rate to serviceable inventory level. As a result, an optimal open-loop plan can be provided as solution of a Mean Value problem that has its chance-constraints regulated by this gain.

The remainder of this paper is organized as follows: the section 2 discusses about revising a discrete-time stochastic quadratic model with chance-constraints for representing a closed-loop supply chain problem; the section 3 shows how to solve this problem by means of a minimum variance problem to reduce the variability of serviceable inventory variable. An equivalent deterministic problem is used then to provide an optimal open-loop solution. Section 4 presents a simple example where open-loop optimal plans are provided and compared as a result of the solution of the problem with and without gain.

2. THE STOCHASTIC MODEL

Figure 1 illustrates the forward and reverse channels of a closed-loop supply chain. Note that there are two warehouses in this figure: the first one (serviceable unit) stocks manufactured and remanufactured (or refurbished) products that meet the market demand, and the second (returnable unit) stores the collected products. Note that used-products stored in returnable unit are inspected and they can be remanufactured (refurbished) or disposed.

It is worth emphasizing that the demand for the product must be met by the combination of manufactured and remanufactured/refurbished products. Some supposed features and properties from the exhibited system in Figure 1 are: a) demand “d” is a normal random variable that follows a stationary stochastic process; b) the return variable is assumed here deterministic and known; c) there is a return delay that is related to life-cycle of products collected from the market; d) both manufacturing and remanufacturing/refurbishing processes have upper limits of processing; e) similarly, it is considered upper limits of storage in the serviceable and returnable warehouses; and e) used-products may be disposed after being collected. There are two main reasons to discard a used-product: the first one is a technical justification that occurs when the collected product is not appropriated to reuse anymore; and the second has a financial justification, in which the action of remanufacturing (or refurbishing) an excessive number of products can significantly raise the serviceable inventory levels, what can bring, as a consequence, a huge grow of the overall costs.

2.1 Inventory-Production System

The inventory-production process, illustrated in Figure 1, can mathematically be modeled by a discrete-time stochastic control system with two state variables, which are described by the *inventory* levels of the unities 1 and 2, and three control variables that are related to *manufacturing*, *remanufacturing* or *refurbishing*, and *discard* rates. Next, the main aspects of this formulation are presented.

The discrete-time stochastic control system is described by the following two difference equations, which represent, respectively, the inventory balance systems related to forward and reverse channel of the supply chain; see Silva Filho (2014) and Silva Filho & Andres (2016).

$$x_1(k+1) = x_1(k) + u_1(k) + u_2(k) - d(k) \quad (1)$$

$$x_2(k+1) = x_2(k) - u_2(k) - u_3(k) + r_\tau(k) \quad (2)$$

where, for each period k , the notation is given as follows:

متن کامل مقاله

دریافت فوری ←

ISIArticles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات